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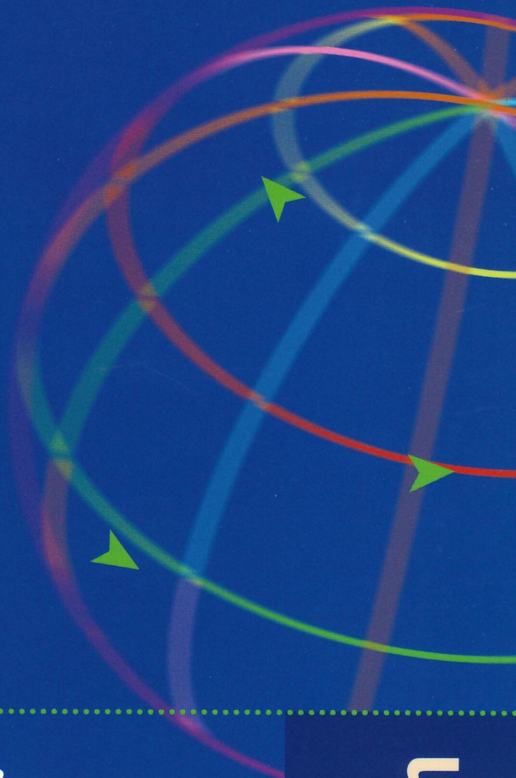

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Higher education in a globalized world: governance, competition and performance

éducation

Higher education in a globalized world: governance, competition and performance

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Introduction

Mathias DEWATRIPONT and Luc WILKIN

This book puts together a number of research outputs which are the result of a multi-university project funded by the Belgian Federal Scientific program "IAP", which stands for Interuniversity Attraction Pole. It is the third such book[1], and it reflects on a project focusing on the analysis of universities whose funding started in 1996.

Over these last 12 years, this topic has attracted more and more attention in social sciences, especially in economics since the connection between the functioning of higher education and economic growth is increasingly recognized. The various chapters of this book, many of which have been published in international academic journals, are therefore interesting from a double perspective : from a "pure research" point of view but also, for many of them, from a public policy point of view.

This is especially true for the first set of chapters, which focus on the *organization of higher education systems*. There are indeed many policy discussions in Europe on this topic, both in terms of the need to raise the inflow of (public and private) money into the higher education system as well as the need to alter some of its rules of functioning to improve their "value for money". There is also a great deal of interest in the evaluation of existing reforms, like the Bologna process which favors compatibility between teaching programs and therefore the mobility of students. Several chapters of this book take an explicit policy perspective on these issues.

The next topic discussed in this book concerns the positioning of *individual higher education institutions*. These chapters are more theoretical, building on the economic theory of contracts as well as on game theory and "industrial organization". Nonetheless, the results derived using these theoretical models also have concrete implications about the strategies of higher education institutions, starting from the multi-tasking nature of their mission.

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[1] The previous two, also edited by M. Dewatripont, F. Thys-Clément and L. Wilkin, were entitled *The Strategic Analysis of Universities : Microeconomic and Management Perspectives* and *European Universities : Change and Convergence ?*, and were published respectively in 2001 and 2002 by the Editions de l'Université de Bruxelles.

The same is true for the last two topics, which concentrate on *individual behavior*, of both *researchers* and *students*. These chapters combine theoretical and empirical methods to discuss the role of career incentives of researchers and the adoption of new technologies by students as well as the predictability of their success rate.

The book thus goes from a 'macro' perspective, looking at higher education systems, to a 'micro' perspective, looking at individuals, with as intermediate step an analysis of individual universities. In doing so, it builds on a variety of approaches, from microeconomic theory to empirical approaches. These are also diverse, since some rely on econometric analyses, while others concentrate on evidence collected from surveys. They all share the goal of an improved understanding of European higher education, both as a scientific objective and also as a policy objective.

The organization of higher education systems

The first four papers in this part of the book address various facets of existing debates concerning the reform of higher education in Europe.

The paper by Reinhilde Veugelers and Frederick van der Ploeg, entitled "Reforming European universities : Scope for an evidence-based process", starts with a discussion of the state of higher education in Europe relative to the United States. It stresses that, in comparison with the US, Europe has fewer world-class universities, and that its overall graduation rate is lower (but rising). On the other hand, Europe produces more graduates in mathematics, science or technology (but has fewer researchers in these areas than the US), and more PhDs. Finally, Europe does well in terms of the number of international publications, but less well in terms of citations : quantity is therefore good, but quality is to some extent a problem. After focusing on performance, the authors discuss remedies. They argue for more money – given that European universities suffer from much lower revenue than their US counterparts – but also improved governance, meaning more autonomy from public authorities but also more accountability, in particular through competition (to avoid the risk of monopolization of some markets where a lot of mergers/rationalization have been encouraged). Finally, they evaluate the chances that these reforms might be acceptable to higher education 'stakeholders'. In particular they discuss Faculty responses to a set of questions concerning reforms. While differences do exist between countries, one sees strong support for student selection (with resistance in Sweden and Belgium, though), and more qualified support for student fees (with opposition in Scandinavia) as a way to raise university budgets. The same is true for increased competition (which does raise eyebrows in France and, interestingly, the UK), while 'privatization' meets the strongest objections.

This paper is in the same spirit as the one by Philippe Aghion, Mathias Dewatripont, Caroline Hoxby, Andreu Mas-Colell and André Sapir, entitled "Why reform Europe's universities ?". This one focuses on the fundamental research mission of universities. Looking at the Shanghai world ranking of universities, it also stresses US dominance when looking at the Top 50 universities in the world. Europe starts doing better when looking at the Top 100, 200 and 500 universities. Moreover, small countries from Scandinavia and the Benelux, and especially Switzerland, do quite well on a per-capita basis. While university rankings do have shortcomings (for example, the Shanghai ranking puts much too little weight on Social Sciences and Humanities, beyond focusing solely on basic research), they do provide useful information on relative country performances. The paper therefore reports on the results of a survey collected by the authors from the European universities that belong to the Shanghai Top 500. Thanks to a 33 % response rate, this survey provides information about the size, funding and organization of top European research universities. One thing that emerges clearly is that there exist several successful national "models" of organization of higher education, with for example a much more "market-oriented system" in the UK relative to Sweden and Switzerland, to focus just on successful European countries. This being said, econometric analysis suggests that a university Shanghai ranking is boosted by both better funding and more autonomy (specifically, budget autonomy for the university with respect to the public authorities). Moreover, the results show a complementarity between funding and autonomy : it looks like one more Euro of funding per student has an effect which is twice as big for universities that enjoy budget autonomy relative to those that do not. While these results are only suggestive and further research is needed, they point to an interesting policy direction, especially since the authors show that the same effects are at play when looking at the determinants of patenting in the US : more money given to universities of a given US State raises subsequent patenting in that State and the effect is twice as big if the State has autonomous universities.

Taken together, the two papers described above can be used to advocate more funding for universities, more autonomy from public authorities and more accountability, especially through more competition. The next paper, by Françoise Thys-Clément, entitled "Research and higher education in a federal system : The need for a European University Charter", is complementary to this policy line. It pushes mainly for two ideas : (i) the public good nature of basic research, which pleads for public financial intervention, in particular at the aggregate, i.e. European level, given the importance of international spillovers in this area; (ii) the need for establishing a 'university charter' at the European level, in order to guarantee stable funding for higher education institutions, as well as shared principles of governance. This is indeed important because, in the current debate about 'university accountability', one has to keep in mind the specific missions that universities are the only institutions able to fulfill, namely the training of Europe's youth and the advancement of basic research. While it is a good idea to also improve universities' ability to transfer knowledge towards innovation and growth, it is crucially important that this third mission not be achieved at the expense of training or basic research: if this were the case, the very productivity of knowledge transfer could in fact be greatly diminished.

The fourth paper, written by Marcel Gérard and entitled "Financing Bologna : which country will pay for foreign students ?", looks at one issue which is increasingly important in the current context of European reforms : the nature of student financing in the Bologna context of increasing student mobility across European borders. As the author stresses, the current system of (mostly) public financing of university studies in Europe, coupled with the nondiscrimination principle between EU citizens, has incoming foreign students largely funded by host countries. Since national Governments naturally put less weight on foreign students than on national students in their social welfare function, this leads to underinvestment in the quality of higher education in comparison to the social optimum. The paper then identifies conditions under which a move to a system where the country of origin of students pays for the cost of university studies represents a Pareto improvement, even though it manages to meet only part of the distance to the social optimum. This conclusion is very relevant, because one can indeed foresee that the Bologna reforms will significantly raise student mobility, at least at the Master level. And one can moreover foresee that, in the absence of a move away from the current financing rules, countries which attract many foreign students will unavoidably raise tuition fees, simply in order to stop significant subsidies in favor of foreign students. While raising tuition fees is not necessarily a bad idea per se, doing it simply as a response to the current European context is not advisable as a policy.

The next paper, by Stijn Kelchtermans and Frank Verboven, entitled "Regulation of program supply in higher education. Lessons from a funding system reform", considers an alternative to providing the higher education sector in Europe with more revenue: raising its efficiency by 'rationalizing supply'. This idea of shrinking the supply of degrees is on the table in various regions, including Flanders. This may make sense if there is a lot of duplication and if students are ready to travel a little farther in order to gain access to their favorite degree. However, the balance between the cost saving and the reduced student welfare is an empirical question. The authors conduct an econometric analysis of this question which stresses that, while students are very determined in their decision to pursue higher education, which implies a low elasticity of higher education demand with respect to the availability of degrees being offered near their home, there is much higher elasticity with respect to the *type* of program being chosen. Concretely, students have a significant probability of changing their chosen field of study depending on what is available nearby. This is a cost of a reduction in the diversity of the supply of educational programs. Balancing these different effects leads the authors to conclude that only few programs should optimally be cut, which means that cost savings cannot be hoped to provide a credible alternative to the need to raise the infusion of money into the higher education system.

The final paper in Part I of this book, written by Thomas Gall, Patrick Legros and Andrew Newman and entitled "The timing of education", takes a somewhat more abstract but nonetheless important perspective. It discusses the desirability of providing higher education relatively 'early' or relatively 'late' with respect to labor market choices. For example, business degrees like MBAs are undertaken after people have already acquired some labor market experience in the US but this is typically not the case in France. This is in line with more general trends, which indicate that higher education is acquired at a younger age in France relative to countries like the US or Switzerland. This fact has implications for student choices because the amount of information available at the time the choice is made is clearly not the same in the two systems. The authors show that 'late education' systems are better at coordinating educational investments *within firms*, while 'early education' systems provide incentives more in line with *expected returns* in the labor market. They argue that recent trends in the way firms are organized, for example linked to the globalization of production within firms, tend to favor ‘late education’ systems, because it becomes harder to provide ex-ante rewards to educational investments. This prediction, which is in line with the need to boost ‘lifelong education’ in a world where the demand for skills is both rising and possibly becoming less predictable, definitely opens an interesting research avenue.

Individual higher education organizations

The three papers in this second part of the book all present theoretical models, and all analyze optimal strategies of individual higher education institutions.

The paper by Alexis Walckiers, entitled “Multi-dimensional contracts with task-specific productivity : an application to universities”, considers the multi-task nature of academia, focusing on the core missions of teaching and research. It considers the optimal contract an academic institution can offer its employees under the assumption that it is faced with heterogeneous individuals, which differ in their ‘effort cost’ of carrying out these two missions. Technically, the institution is facing ‘multidimensional adverse selection’. In this literature, one key question is whether the optimal contract involves ‘bundling’ or not, i.e. whether individuals can be thought of being offered two separate contracts or a single one which involves a specific combination of the two missions to be performed against a single compensation package. Under adverse selection, the institution has to be concerned about getting its missions done without spending too much for it. For example, if it is facing individuals whose cost of performing the teaching mission can be either 10 or 20 and whose cost of performing the research mission can also be either 10 or 20 (and the institution does not know whether it is 10 or 20, only the individual knows it), making sure both missions are undertaken by these individuals costs a price of 20 per mission if ‘single-mission contracts’ are offered. But assume now that a given individual can fulfill both missions, and that moreover, to take an extreme case, there is perfect negative correlation in the adverse selection, i.e. somebody whose cost of teaching is 10 (resp. 20) has a cost of research of 20 (resp. 10) : in this case, rather than the above-mentioned single-mission contracts, it is better to offer a unique two-mission contract at a price of 30, which therefore allows the institution to save 10 per individual. The author generalizes this point in his analysis, while explaining how (partial) negative correlation is a natural assumption, in a situation where individuals are able to perform both missions but have limited time overall. This analysis thus sheds light on one reason which favors the emergence of “research university contracts”, which combine these two missions in a given proportion.

The next paper, written by Axel Gautier and Xavier Wauthy and entitled “Teaching versus research : The role of internal financing rules in multi-department universities”, also looks at multi-tasking within universities. But it focuses on moral hazard rather than adverse selection, i.e. ‘hidden actions’ rather than ‘hidden information’. Moreover, it builds on the idea that universities typically have multiple departments, teaching and doing research in a variety of scientific fields. This very often involves redistribution between departments, a feature which can have an adverse effect on teaching and research effort since it reduces the return of such effort for one’s own department. However, by giving incentives related to the *relative* quality of teaching and research across departments, the university can mitigate this problem. Moreover, even if individuals are intrinsically more motivated by research than by teaching (for example because outside rewards are more driven by research performance, which is more easily observable than teaching performance), institutions can alter the balance of incentives by basing research budgets on student numbers, thereby introducing additional internal incentives favoring the teaching mission. The extent to which they will want to push in this direction is naturally related to their declared mission, which can be oriented more towards being a 'research university' or instead towards being a 'teaching college'. The considerations detailed in this paper are in fact very relevant in the current academic environment, which is becoming more and more competitive, prompting universities to think harder about optimizing their internal reward structures in order to better achieve their mission.

The third paper in this second part of the book, by Eve Vanhaecht and Wilfried Pauwels and entitled "University competition: Symmetric or asymmetric quality choices?", looks at competition between universities. It allows for both 'horizontal differentiation', for example based on geography, with students ranking different universities differently depending on where they live, and 'vertical differentiation', which concerns 'quality'. And here, while all students prefer higher-quality universities, they may end up making different choices because with higher quality comes a higher difficulty of obtaining a degree, and this tradeoff is resolved differently by students who differ in intrinsic ability. Interestingly, whether universities end up choosing to offer symmetric or asymmetric quality levels in equilibrium depends on student mobility costs: when these are low, universities end up being differentiated in the quality dimension, while when mobility costs are high, they tend to be similar. This is interesting, because it is consistent with the US-EU comparison, with higher mobility in the US and more differentiated universities relative to the European landscape. Another interesting result in the paper concerns the effect of competition on quality provision: the need to compete to attract students ends up raising teaching quality. This effect should be kept in mind when thinking of 'supply rationalization', a reaction to the Bologna process which should not be pushed too far.

Researcher behavior

The two papers in this third part of the book are concerned with individual researcher behavior. The paper by Doh-Shin Jeon and Domenico Menicucci, is entitled "Money, fame and the allocation of talent: Brain drain and the institution of science". It links individual researcher incentives with the broader question of the allocation of the pool of skilled individuals in academia and in the private sector, at the overall level of the economy. The authors focus on two differences between the two sectors: (i) the fact that scientists can derive benefits from peer recognition, and (ii) the fact that individual performance may be more easily measured in basic science, thanks to the peer-review system. With these two elements in mind, a 'good institution of science' can mitigate a 'brain drain' from academia to the private sector which can occur if the latter offers higher rewards for good performance. This may lead to an earning structure that is optimally flatter in academia than in the private sector. The paper also discusses the risk of raising performance-related monetary rewards in science, in terms of a potentially excessive shift away from basic science and in favor of applied research. At a time where there are many calls for universities to become ‘more commercially-oriented’, this warning is very important. One should indeed not forget that applied research cannot flourish without a solid basic research foundation.

The paper written by Tom Coupé, Valérie Smeets and Frédéric Warzynsky and entitled “Incentives, sorting and productivity along the career: Evidence from a sample of top economists” follows a different path. It takes advantage of the richness of the data on individual research productivity – that is, their publication record, to look at the relation between career incentives and the dynamics of research productivity. Focusing on a sample of 1,000 economics professors, it documents the link between production and subsequent promotions, with a diminishing intensity of this relation for higher levels of seniority. In turn, the paper also documents that the prospect of promotions raises productivity, with a reduction of this productivity over time. There is also evidence of a sorting process, namely the fact that more productive individuals tend to join higher-ranked universities. In a European context with higher mobility across countries and institutions, this factor will strengthen research incentives. While this is good as far as research is concerned, one should keep in mind, in a multi-tasking setting, the need to simultaneously strengthen incentives for the provision of teaching quality, if one wants to avoid this task from being crowded out.

Student behavior

The two papers in the last part of the book look at different aspects of student behavior.

In the first one, written by Luc Wilkin, Périne Brotcorne and Ilaria Faccin, “Clicks and bricks: tuning the promises of information and communication technologies (ICT) with students’ practices”, the authors provide a down-to-earth account about the way ICT are mobilised and integrated into university students’ daily academic activities (with a particular focus on their information seeking behavior). Looking at the students’ point of view, this research tries to better enlighten the place of the electronic information resources compared to “traditional” (paper) and “informal” (relational) ones. Thanks to an extensive empirical study based on a twofold research methodology (questionnaires and open ended interviews) they explore factors (discipline and year of study) potentially moulding the students’ use/non use of information technologies within the university setting. Internet has a sort of tailored role in the information seeking strategies of students: an important source when facing a new topic, a trigger for further research and a useful tool to provide complementary punctual information. Although students perceive it as weak in terms of scientific reliability, they prefer to address their research to traditional channels (library, and printed-based resources) when looking for in depth information. Students shape their information seeking strategies in a pragmatic way, according to what can be defined as a ‘goodness of fit’ criterion taking into account the suitability of the tool with disciplinary contents and contents related constraints. Therefore, hard sciences students showed a strong preference for the Internet as an information resource (without neglecting books and scientific journals); whereas soft sciences students were more ‘literate-print-based-oriented’ (without neglecting the Internet). Seniority emerges also as an important crafting factor; still, the disciplinary effect was rather reinforced by seniority. These findings show that students’ information seeking patterns are far beyond the simple and univocal use of the Web, doomed to replace and substitute traditional or informal resources.

Finally, the paper written by Jean-Philippe Vandamme, Nadine Meskens and Juan-Francisco Superby and entitled “Predicting academic performance by data mining methods”, considers a survey of students from three French-speaking Belgian universities. The goal is to look at different methods in terms of their ability to predict potential first-year success in one’s studies, a big concern in systems like the Belgian one with free entry to the university. The idea is to try to classify students into three groups according to success probabilities, to be able to concentrate resources on those students whose success rate could be most increased by remedial activities. The paper establishes the key importance as determinants of success of: (i) high school achievement and background; (ii) the level of involvement at the university (e.g. class attendance); and (iii) the level of personal motivation and confidence. It then presents the effectiveness of three classification techniques – decision trees, neural networks and linear discriminant analysis – in their ability to successfully classify students, showing that they roughly do equally and only moderately well in this respect. These approaches nonetheless offer interesting avenues towards an important goal, achieving a higher graduation rate to be able to position one’s region or country more favorably in the competition between “knowledge-based societies”.

Note that this question of graduation rates in European countries was one of the dimensions considered by the first paper, by Veugelers and van der Ploeg, to evaluate the performance of European higher education systems. Taken together, these two papers illustrate how one can usefully think about key policy questions like this one by relying on complementary scientific approaches.

Part I

Organization of higher education systems

Reforming European universities: Scope for an evidence-based process

Reinhilde Veugelers [1] and Frederick van der Ploeg

Summary

Universities are key players in the successful transition to a knowledge-based economy and society. However, this crucial sector of society needs restructuring if Europe is not to lose out in the global competition in education, research and innovation. To allow a more evidence based process of reforms of higher education, this contribution reviews the trends in performance, funding and governance of European universities. It also brings on board some evidence on support for the reform process. The analysis shows that, while EU universities have improved their quantitative performance on teaching and research, it needs to further improve especially on the quality dimension. The link between governance, funding and performance is not obvious and needs still further data and research. Nevertheless, the preliminary evidence so far seems to suggest that society supports a multitude of university structures, to respond to a heterogeneous set of preferences. This calls for granting universities the space and trust to develop autonomously their own strategies and structures. Public and private stakeholders should provide the funds for universities to develop their agenda, while holding them accountability for delivering results. Establishing a large, integrated market for higher education and research in Europe, would provide an environment for European universities to develop their comparative advantages, making them stronger players on the world scene.

1. Introduction

Universities are among the key actors in constructing a knowledge-based society. Through their teaching, they disseminate knowledge and improve the stock of human capital; through the research they perform, universities extend the horizons of knowledge; and by their other activities, they transfer knowledge to the rest of society, work with established industry and create new companies.

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[1] The views expressed in this paper do not necessarily reflect the views of the European Commission. The author would like to acknowledge the financial support of the PAI Project "Governance of Universities" P6/09 and the Research Fund of the Katholieke Universiteit Leuven.

As Europe approaches the world technology possibility frontier and leaves the era of catching up behind, innovation and highly-educated people have become crucial drivers of its growth potential. If forces are indeed to be mobilised in Europe to create the most competitive economy and knowledge-based society of the 21st century, European universities have to play a central role. But most European universities do not seem currently to be in a position to achieve their potential in a number of important ways. In a still too fragmented European higher education and research area, universities are hampered by a combination of excessive public control, bad governance coupled with insufficient funding opportunities. As a result, compared with their counterparts in the US, Australia and other countries (perhaps also China), they are behind or falling behind in the increased international competition for talented academics and students, and miss out on fast-changing research agendas, innovative opportunities and teaching curricula.

Modernization of Europe's universities, involving their interlinked roles of education, research and innovation, has therefore rightly been acknowledged as a core condition for the success of a move towards an increasingly global and knowledge-based economy. Various policy communications have identified the main items for change, at the level of the EU and also in many European countries [2]. Spurred by the Bologna process, many countries have started designing a process of reforms. However, few countries make them national priority. Yet these changes are crucial to regenerate Europe's growth capacity. Perhaps, national governments rightly give priority to giving funds to primary and secondary education rather than to university education. But reform of the university system is not only a question of restructuring its governance or pumping more public money into the system. With a carefully designed social loans system of the type implemented in Australia, it may well be possible to raise private funds from higher tuition fees without sacrificing accessibility to higher education.

In this contribution we give a review of the evidence on the performance of European universities with respect to education, research and knowledge transfer (Section 2). Having established the problems of European universities to deliver, particularly on the quality dimension, we examine two important drivers of university performance: governance and funding (Section 3). With only limited evidence available on how governance and funding are linked to performance, the implications for the policy agenda reforming European universities remain tentative (Section 4). We also provide evidence on the heterogeneous opinions and preferences of some of the stakeholders in the reform process (Section 5), before we conclude with a call for more data & analysis to support a more evidence-based reform process (Section 6).

[2] E.g. "Mobilising the Brainpower of Europe: Enabling Universities to Make their Full Contribution to the Lisbon Strategy", COM(2005) 152 of 20 April 2005 and Council Resolution of 15 November 2005.

2. Performance of Europe's universities

With universities being an important actor in delivering economic development, either through their education and/or through their research activities (see a.o. Sianesi & Van Reenen, 2003; van der Ploeg & Veugelers, 2008; for a review of the theoretical and empirical literature on this), and with the public good nature of the services provided by universities, both in education and research, there is a clear case for policy to be concerned about how well their universities are performing, and to intervene if necessary. This holds particularly in those countries or regions that have moved closer to the world technological frontier, and want to become leading knowledge based societies (Aghion, 2006). This section takes a closer look at the performance of universities in Europe.

It is well recognized that European universities have several missions which are centrepiece contributions in a knowledge-based society: teaching, research and the transfer and exchange of knowledge with other parts of society. While education, basic research and transfer of knowledge are heavily interconnected within the university as institute, the academic literature, the statistics and the policy discussion mostly focus on one of these areas only. They thus ignore most of the time the multi-tasking challenge of universities having to balance the various activities which can be sometimes substitutes and other times complements. In the reminder of this contribution, we will therefore also often have to resort to a focused discussion of each of the activities of the university separately.

A. Performance of European universities on international rankings

By now a wide series of rankings abound, comparing the performance of universities across countries[3]. The most 'mediatic' representatives, and also the ones most criticised, are the *Times Higher Education Supplement* (THES), and the Shangai Jiao Tong University Ranking[4]. Both rankings, THES and Shanghai, paint a somewhat similar picture of Europe lagging behind especially at the top, and especially the larger continental European countries. Overall, the results from the rankings indicate the lower performance of Europe's universities relative to the US, especially at the top. Although these rankings are heavily criticized, they are nevertheless influential and are therefore interesting to examine in some more detail.

1. The Times Higher Education ranking of universities

The THES ranks top 200 universities across the world on the basis of peer review, recruiter review, international faculty, international students, student/staff ratios and faculty citations scores. The results reported in Table 2 indicate that the Top-50 includes almost only universities from countries with an Anglo-Saxon system of education. Continental Europe (excluding Switzerland) only has three universities in the Top-50 in 2005 and this has dropped to only two in 2006. When extending to the

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[3] For a discussion on the how to use rankings, see UNESCO, Berlin principles on ranking of higher education institutions, http://www.che.de/downloads/Berlin_Principles_IREG_534.pdf.

[4] Other rankings are Center for Higher Education German, bibliometric ranking by Leiden and ranking web of universities by CSIC Spain.

Top-200, the gap is less strong. Continental Europe manages to have 48 universities in the 2006 Top-200. This reflects that the performance gap of continental Europe is most acute at the top.

Table 1 Number of universities per country in the THES 2006 Top-50

Top-50	*2005*	*2006*
US	20	22
UK	8	8
Australia/New Zealand	6	7
Asia excl. Hong Kong and Singapore	4	4
Hong Kong/Singapore	4	2.5
Canada	3	2.5
Switzerland	2	2
France	2	2
Germany	1	0
Total	50	50

2. The Shanghai research ranking of universities

Shanghai ranks universities on a set of indicators, measuring their research performance. The indicators include (i) the number of alumni winning Nobel Prizes; (ii) the number of university faculty winning Nobel Prizes; (iii) the number of articles published in *Nature* and *Science*; (iv) the number of articles published in ISI WoS journals; (v) the number of highly cited researchers; (vi) size of universities. Brueghel researchers (Aghion *et al.*, 2007) have aggregated these Shanghai rankings per country – see Table 2. The US completely dominates all European countries in the Top-50. Only the UK and Switzerland rival the US on a *per capita* basis. Nevertheless, the EU has many good universities in the second and third tiers. It suggests again that what Europe lacks most is top-class universities.

Both rankings, THES and Shanghai, paint a somewhat similar picture of Europe lagging behind especially at the top, and especially the larger continental European countries. Although contrary to the THES, the Shanghai ranking is mostly based on publicly available information, it remains nevertheless controversial because of the weights attached to the various dimensions. It also focuses on research, remaining silent on teaching performance.

Table 2 Aggregate Shanghai Rankings

	Top-50	*Top-200*	*Top-500*
CH	97	228	230
UK	72	98	124
CAN	39	63	104
AUS	0	66	101
US	100	100	100
EU-15	13	41	67
GER	0	37	67
EU-25	10	32	54
FRA	3	29	45
JAP	14	24	27

Source: Brueghel PB 2007/04, Why Reform Europe's universities?
Note: The best university in the Top-50 is given a score of 50, the next best university is given 49, and so on. For each country (or region), the sum of Top-50 Shanghai rankings that belong to this country is summed, and divided by the country's population. Finally, all the country scores are divided by the US score, as benchmark. This gives the Country Performance Index for the Top-50 universities. The same logic applies, respectively, to the Top-200 and Top-500.
Selected countries are ranked according to their score on Top-500.

B. Performance of European universities on education, research and technology transfer

Rankings can be criticised for many things [5]. This section takes a look at the more standard official statistical evidence that is available to measure across countries the performance of universities on higher education and research including the quality dimension of educational and research performance.

1. Performance of higher education enrolment and graduation rates[6]

a. Proportion of EU population that graduate from higher education is relatively low

Table 3 Higher education attainment rates
(% of population aged 25-64 with completed tertiary education (2005))

US	*JAP*	*EU-25*	*FIN*	*DK*	*SE*	*UK*	*GER*	*FRA*
38.4	37.4	*22.8*	34.6	33.5	29.2	29.6	24.6	24.9

Source: EC-ENTR, European Innovation Scoreboard 2007.

Table 3 indicates that on average the higher education attainment in the EU is around 23 %, which is considerably below levels in the US and Japan. Nevertheless, within the EU there is an important heterogeneity. For example, Finland and Denmark, the best performing EU countries, come close to the US level.

[5] See footnote 4.
[6] Unless noted else, the source of information used is OECD (2006), Education at a glance.

b. Relatively few young people in EU enrol in higher education but enrolment is growing strongly

Furthermore, in comparison with its most important competitors, higher education institutions in the EU attract a lower proportion of secondary school leavers. This implies that higher education in Europe is still not an attractive option for a significant part of pupils having completed upper secondary education. About 25 % of young people aged 18-24 years were enrolled in higher education in the EU-25 in 2002, which is much lower than in the US (37.7 %). In the US tertiary students start to study on average at an earlier age than in Europe. Almost 40 % of 18-year-old in the US participate in higher education, which compares to only about 15 % in the EU

However, the EU is catching up. Despite low birth rates in the 1980s, the number of higher education students in Europe is increasing as a result of growth in enrolment rates. The number of higher education students increased in the EU during 1997-2002 by 16 %. This corresponds to an average of 3.1 % per year, which exceeds the annual growth of 2.2 % in the US and 0.1 % per annum in Japan.

c. Graduation rates in EU are below OECD average

Improving the rate of participation in higher education of talented young people is a challenge in most countries, especially from socially disadvantaged social groups. Furthermore, it is necessary not only to reach new categories of students, but also to make them succeed. At present, too many enrolled students leave the European universities without an academic degree. According to OECD data, survival rates in higher education in the 13 EU countries for which data was available amounted to only 66 % in 2000, compared to an OECD average of 70 % and a rate of 66 % in the US, 79 % in Korea and 94 % in Japan [7]. Survival rates in Europe vary widely between countries with highest rates in Ireland (85 %) and the UK (83 %) and relatively low rates in Sweden (48 %) and Italy (42 %).

d. EU produces more mathematics, science and technology graduates than US but has fewer researchers in labour market

Table 4 shows that Europe produces significantly more graduates in mathematics, science and technology than the US and Japan. And the number of graduates in these fields in the EU is further increasing (by about 30,000 or over 4 % in 2003). However, with a growth of over 30 % per year, China overtook the EU in 2003.

Advanced graduates in Europe use their competencies and skills in a wide variety of economic sectors, but it seems that their *research* potential remains relatively under-utilised. In 2001 some 1.8 million full-time equivalent (FTE) personnel were employed in R&D in the EU of whom about one million were considered researchers. That leaves the EU with fewer active researchers in the labour market than the US. This situation is partly due to differences in the functioning of the labour market, but also due to the 'brain drain' from Europe to the US. About 400,000 Europeans

[7] Survival rates are calculated on the basis of the number of graduates divided by the number of new entrants at the typical age of entrance.

with a scientific and technical education are currently living in America, of whom about 120,000 are employed as researchers (Source: EC-DG EAC).

Table 4 Number of graduates (ISCED 5 and 6) in mathematics, science and technology and number of researchers (in 1000) in 2001

Region	*MST graduates*		*Growth per year in 2001-03 (%)*	*Researchers 2001*	*Number of researchers per 1000 labour force 2003*
	2001	*2003*			
EU-25	681	740	+4.2	1084	5.5
US	380	431	+6.5	1261	9.0
China	464	810	+32.1	743	1.0

Source: EC-DG EAC.

e. EU produces more Ph.D.'s than its major competitors

The EU-19 as a whole outperforms the US and Japan in number of doctoral degrees awarded with Germany first and the UK second – see Table 5. The EU managed to increase its share further in 2004: almost twice as many Ph.D.'s each year graduated from European universities compared to the US. For S&E students these positive trends are even more outspoken.

Table 5 Trends in shares of OECD doctoral degrees awarded

	Share in OECD total doctoral degrees awarded		*Share in OECD total S&E doctoral degrees*	
	2000	*2004*	*2000*	*2004*
EU-19	47 %	50 %	50 %	57 %
US	30 %	27 %	27 %	25 %
JAP	15 %	8 %	15 %	9 %

Source: OECD, STI Scoreboard, various issues.

However, as Table 6 illustrates, the US make greater efforts to attract students from other countries than Continental Europe. Foreign students in the US represent 41 % of all doctoral degrees in S&E, which is only matched by the UK in Europe.

Table 6 Doctoral degrees earned by foreign students (2005)

	US	*UK*	*GER*	*JAP*
Total number of doctoral degrees *in S&E* by foreign students	11516	4100	2417	792
Foreign doctorates as % of all earned doctorates *in S&E* in country	41.2 %	42.0 %	24.7 %	10.3 %

Source: NSF, Science and Engineering Indicators 2008.

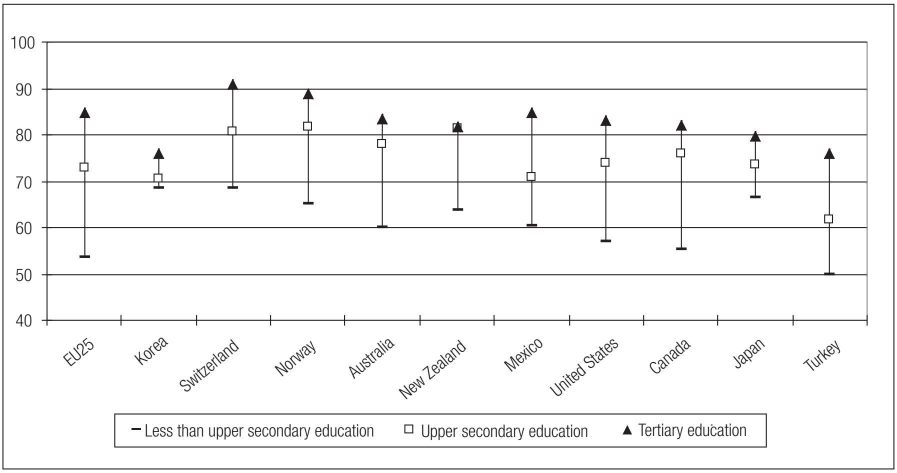
f. Tertiary education leads to higher employment, lower unemployment and higher earnings, also in EU

We see from Figure 1 that the employment rate of holders of a tertiary education is significantly higher than for people achieving only lower levels of education[8]. In the EU the employment rate of people with tertiary education is 85 %. On the other hand, the employment rate of people with less than upper secondary education is 54 %. Almost all the countries in the comparison perform better than the EU as concerns the employment rate of people with low qualifications.

Table 7 indicates that the unemployment rate of tertiary educated is somewhat higher in the EU as compared to the US and it varies across EU countries (ranging from 7 % in Spain to 1.6 % in Austria), but these figures are strongly correlated with the overall performance of a country's labour market. Expressing the unemployment rate of the tertiary educated relative to the unemployment rate of those with upper secondary education shows comparable outcomes for the EU and the US, but a considerable variance within EU countries. Italy, Spain and France combine above average unemployment rates of people with tertiary education with the smallest increment in employment probability when obtaining higher education. Finland and Germany enjoy the highest increment in the chance of getting a job after graduating from higher education.

Furthermore, Figure 2 illustrates that average earnings increase with education level. Indeed, average earnings are almost twice as high for those with higher education than for those with only lower-secondary attainment.

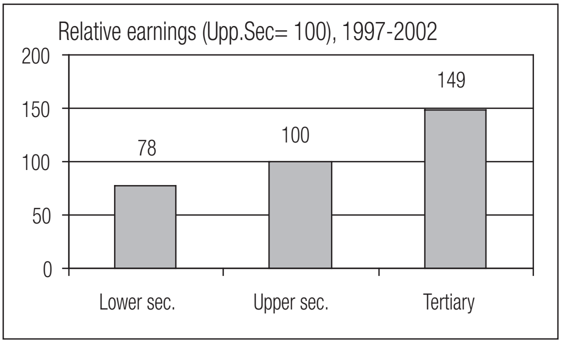
Figure 1 Education levels and employment rates for age group 25-64, 2002



Source: DG Education and Culture. Data: Eurostat (LFS), OECD (Education at a Glance.

[8] There is also a clear link between educational attainment and unemployment rates. The unemployment rate of the active population in the EU in 2003 was four percentage points lower for people with higher education level than for the population as a whole and 7.5 percentage points lower than for those with less than lower secondary education.

Figure 2 Education levels, earnings and lifelong learning participation of population aged 25-64 in EU-25



Source: DG Education and Culture. Data: OECD, Eurostat Labour Force Survey.

Table 7 Unemployment rates for those with tertiary education (among population aged 25-64, 2002)

Country	*Unemployment rate of tertiary relative to upper secondary*	*Unemployment rate of tertiary educated*
Belgium	0.55	3.1
Denmark	1.06	3.6
Germany	0.49	4.3
Spain	0.78	7.4
France	0.77	5.0
Italy	0.83	5.3
Netherlands	0.89	1.7
Austria	0.51	1.6
Finland	0.47	4.0
Sweden	0.60	2.6
United Kingdom	0.64	2.4
EU-25 average	0.53	4.2
Switzerland	0.92	2.2
Japan	0.73	3.9
United States	0.52	3.0

Source: EU, EEA: Eurostat. Others: OECD, Employment Outlook 2004 and Education at a Glance (2004).

The high increment in employment rate and salary increments for tertiary education in the EU signals the high private incentives for EU individuals to start tertiary education.

2. Performance on research

a. Europe has caught up with US on quantity of publications, but quality still lags behind

Table 8 indicates that the EU has been catching up with the US on number of publications and has managed to bypass the US, currently having a larger share of total S&E publications than the US. But perhaps even more striking is the growth of Asia, and particularly China. In 2005 China ranked fifth in the world behind the US, the UK, Japan and Germany. In 2006 (not shown in NSF 2008), China indeed became the world's second largest producer of scientific knowledge behind the US (Source: SOOS, KULeuven).

Table 8 Share in world scientific publications

	1995	*2000*	*2005*
US	34 %	31 %	29 %
European Union	35 %	35 %	33 %
Japan	8 %	9 %	8 %
RoWest*	6.5 %	6.2 %	6.8 %
Asia	13.6 %	17.0 %	20.6 %
C/SAmerica	1.7 %	2.4 %	2.9 %
RoWorld**	1.2 %	0.6 %	0.3 %

Source: NSF, S&E Indicators 2008.
* RoWest = Canada and other Western Europe; **RoWorld is the residual.

When correcting for the number of researchers as input, the EU shows up with an above OECD average publication-per-researcher rate, larger than the US – see Table 9. Within Europe, especially the UK has a high rate. But also countries like Sweden and Denmark, who have specialised in Clinical & Biomedical research (the most publication-active scientific area), have an above average publication-per-researcher rate.

Table 9 EU performance on scientific publications

US	*JAP*	*EU-25*	*FIN*	*DK*	*SE*	*UK*	*GER*	*FRA*
Share in total S&E Publications (Total = OECD) 2003								
36.1	10.2	*38.8*	0.9	0.9	1.75	8.3	7.6	5.5
S&E Publications per researcher relative to OECD average (1 = OECD = 0.164) 2003								
0.96	0.54	*1.17*	0.77	1.23	1.30	1.86	1.01	1.01
Share of Clinical & Biomedical in S&E Publications relative to OECD average (1 = OECD = 4.6 %) 2003								
1.06	0.91	*1.02*	1.10	1.21	1.16	1.04	1.01	0.91

Source: OECD, STI 2007.

b. In terms of quality of produced research, the EU is still catching up with US

But when assessing the quality of publications, as measured by citations, the evidence is less favourable for the EU. Although the EU has been catching up with respect to citations too, this has been at a less impressive rate than on numbers of publications. The share of the EU in total citations is much lower than the US share. A US publication received in 2005 on average 5.3 citations, a UK publication 3.5 citations, a German one 3.7 citations, and a French one 3.1 citations (a Chinese publication 1.25) (Source: SOOS, KULeuven).

This gap in quality is not only apparent in citations, but also in the number of publications in the top tier journals. While the EU outperforms the US in the Bottom-50 percentile, the share of the US in Top-1 articles is almost double the EU's. Nevertheless we see a catching up of the EU in this Top-1 percentile, but only slowly.

Table 10 Trends in publications shares across the quality distribution

	Share in articles in Top-1 citation pc			*Share in articles in Top-10 citation pc*			*Share in articles in Bottom-50 citation pc*		
	1995	*2000*	*2005*	*1995*	*2000*	*2005*	*1995*	*2000*	*2005*
US	62	60	55	50	45	42	32	28	26
EU	25	26	29	32	35	34	33	35	34
Asia10	5	6	7.5	7	9	12	14	17	21

Source: NSF, S&E Indicators 2008.
Note: Top-1: 99th percentile of citations received (> 21); Top-10: 90th percentile (> 6); the Bottom-50 contains the publications with 0 or 1 citation; 1995 are all 91-93 articles cited by 1995 articles; 2000 are all 96-98 articles cited by 2000 articles; 2005 are all 2001-2003 articles cited by 2005 articles.

Even when normalising with respect to number of researchers, the citations gap remains substantial, as the Table 11 (adapted from Dosi *et al.*, 2006) demonstrates. Again, the UK performs much better than its continental European counterparts.

Table 11 EU performance on quality per researcher

US	*EU-15*	*UK*	*GER*	*FR*
Citations/researcher relative to the US				
100	*47.1*	87.4	56.5	45.8
Top 1 % publications/researchers relative to US				
100	*30.8*	76.9	46.1	38.5

Source: On the basis of Dosi *et al.* (2006).

3. Performance on knowledge transfers to industry

a. No sufficiently reliable cross-country data yet available to measure performance of universities on knowledge transfer

Assessing European universities on how well they are doing with respect to industry science links, particularly in comparison with the benchmark US, is challenging. No good internationally comparable data exist, yet. Only recently, a number of surveys have been conducted across EU countries to assess universities' performance on patents, licensing and start-ups, but these surveys are for the moment still with limited participants and therefore cannot be considered as representative across countries [9].

Despite these caveats, Table 12 provides a summary of the performance of European ASTP and American AUTM affiliated institutions in 2004 on five indicators. Interesting to note is the lower level of research funding in the European ASTP sample as compared to the American AUTM sample. To correct for the gap in funding, performance is scaled relative to per million PPP$ of research expenditures, thus measuring the efficiency of institutes in generating output per dollar spent. The comparison is based on combining results for universities and non-university institutions even though there are marked differences between them, because AUTM only provides full details on all types of institutions combined [10]. Within the European ASTP sample, the limited number of observations precludes any analysis comparing individual countries.

Table 12 Comparison of ASTP and AUTM performance in 2004

	ASTP	*AUTM*	*ASTP relative to AUTM*
Average research expenditures (million US)	*153.2*	*215.7*	
1. Invention disclosures per million	0.56	0.40	*1.40*
2. Patent applications per million	0.14	0.33	0.42
3. Patent grants per million	0.06	0.09	0.67
4. Licenses executed per million	0.13	0.11	*1.21*
5. Start-ups established per million	0.02	0.01	*2.00*

Note: ASTP results are limited to respondents that provide data for both the indicator and for research expenditures. The number of eligible respondents is therefore 59 for invention disclosures, 59 for patent applications, 49 for patent grants, 55 for license agreements, and 61 for start-ups.
Source: Arundel & Bordoy (2006), ASTP report.

The results show that the American AUTM affiliated institutions perform better than the European ASTP institutions on the two patent indicators: patent applications and patent grants per million of research expenditures. Conversely, the performance of the European ASTP members is better for three indicators: invention disclosures, licenses executed (although not on license revenues (not reported)) and the number of established start-ups. These results suggest that the American AUTM institutions are substantially more successful in patenting, particularly for patent applications, but that the European ASTP members are more successful at establishing start-ups,

[9] Proton and ASTP, two associations of Technology Transfer Offices (TTOs) in Europe, are currently carrying out surveys among their members. ASTP surveys are comparable to the American AUTM-surveys.

[10] The average research spending in 2004 by European universities is 96.7 million PPP$, compared to an average of 316.1 PPP$ for non-university organisations, which mostly consists of government research institutes.

although there is no information about the future success of ASTP start-ups, which would be a superior measure of performance.

With none of these surveys yet sufficiently representative, we can only conclude that the EU needs better data to assess the performance of its universities on technology transfer.

C. Summing up

A closer look at the standard official statistical evidence thus shows a nuanced picture on Europe's performance of universities on higher education and research, including the quality dimension of educational and research performance measured across countries:

— The proportion of the population in the EU that has graduated from higher education is relatively low. Relatively few young people in the EU enrol in higher education but enrolment is growing strongly.
— Graduation rates in the EU are below the OECD average.
— The EU produces more mathematics, science and technology graduates than the US, but has fewer researchers in the labour market.
— The EU produces a higher number of Ph.D.'s than its major competitors.
— Tertiary education leads to higher employment, lower unemployment and higher earnings, also in the EU.
— Europe has caught up with the US on quantity of publications, but a gap remains on quality of research as measured by citations in the best journals and Nobel prizes.
— No sufficiently reliable data are available yet to measure performance of universities on knowledge transfer across countries.

Overall the statistical evidence indicates that Europe has made improvements, especially in quantitative terms (number of graduates and number of publications). It also illustrates the heterogeneity within Europe, with a number of countries, particularly the Nordic countries, even outperforming the US on a number of indicators. At the same time, it shows the need for further improvements of the European higher education system, particularly on the quality of education, research and transfer dimensions.

3. Drivers of performance: funding and governance of Europe's universities

What explains these differences in performance of universities between the EU and other international competitors like the US, and among EU countries? Two components always show up in the discussion: funding and governance. These two dimensions will be discussed in Sections 3, A and 3, B, respectively. But beyond funding and governance, also size might matter. Alesina and Spolaore (2003) argue that countries with a large population may benefit from returns to scale and be more efficient in providing public goods and generate higher productivity. Within the context of the market for higher education and research, it is clear from the law of large numbers that in such countries the chances of a genius surfacing is larger than in a small country. This is why it is important to engender competition (as well as cooperation) on a European level. However, the evidence so far fails to support that the number of top universities per million inhabitants is an increasing function of the size of the population (Thissen and Ederveen, 2006). However, historical empirical comparisons neglect the potential of countries with huge and rapidly growing populations like China and India.

A. *Funding*

1. *Funding higher education*

a. *Total investment in higher education in the EU is below key competitors, especially private funding*

Table 13 compares the public and private spending on higher education across countries. *Total investment* in higher education in the EU is about 1.3 % of GDP, which is on a par with Japan, but below the levels of the US (2.7 %). The three best performing EU countries are again the Nordic countries (Denmark, Finland, Sweden), who invest 1.8 % of GDP in higher education albeit clearly below the levels of the best performing OECD countries. The UK is no positive outlier with respect to spending on higher education.

Table 13 Spending on tertiary education as percentage of GDP, 2003

	US	*JAP*	*EU-19*	*FIN*	*DK*	*SE*	*UK*	*GER*	*FRA*
Total	2.9	1.3	*1.3*	1.8	1.8	1.8	1.1	1.1	1.4
Public	1.2	0.5	*1.1*	1.7	1.7	1.6	0.8	1.0	1.1
Private	1.6	0.8	*0.2*	0.1	0.1	0.2	0.3	0.1	0.2

Source: OECD, Education at Glance (2006).

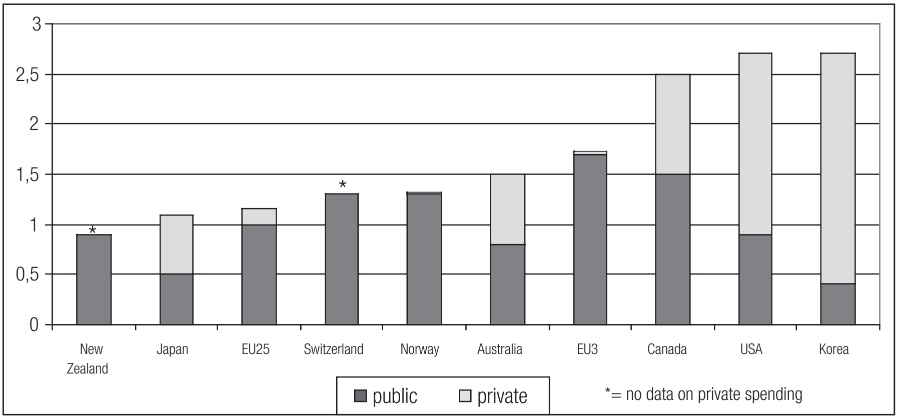
Table 14 Funding per student across EU universities

	*Size **	*Budget per student***
Belgium	21.7	11.3
Denmark	18.2	11.4
Germany	26.2	9.6
Italy	44.9	10.1
Netherlands	21.4	20.5
Spain	44.8	7.0
Sweden	27.1	16.2
Switzerland	12.8	26.2
UK	14.6	24.5

Note: * Average number of students per institute (000); ** = in PPP 000 euro.
Source: *Brueghel PB 2007/04, Why Reform Europe's universities.*

Differences between countries in levels of *total investment per student* are also large as indicated in Table 14. In 2001 the EU-25 spent on average 8,600 Euro per tertiary student, which is only slightly lower than in Japan. In the USA, however, investment per tertiary student is at over 20,000 EUR, more than twice the EU level (Source: EC-DG EAC, 2006). Also within the EU, *spending per student* varies sub-

Figure 3 Total investment in tertiary education as percentage of GDP, 2001



Source: DG EAC on the basis of OECD (Education at a Glance, 2004).
EU averages and non-EU countries are ranked in descending order by spending as a % of GDP. EU3 = Denmark, Finland, Sweden (3 best performing EU countries).

stantially across countries. The Bruegel study reports that the best funded students are to be found in Switzerland and the UK, which also have the smallest institutes. On the other extreme, Spain and Italy have large, but not well funded universities. Germany is also less well funded per student. Sweden and the Netherlands have universities of average size and are relatively well funded per student.

Figure 3 illustrates that differences across countries in spending become even more pronounced when the public versus private source in this funding is considered.

Public investment in higher education in the EU-25 amounted to 1.1 % of GDP in 2003, which is not too different from the US levels. The EU contains the three OECD (and probably world) leaders in terms of public investment in higher education as a percentage of GDP, which are the three Nordic countries: Denmark (1.8 %), Finland (1.7 %) and Sweden (1.5 %). Outside the EU only Canada (1.5 %), Norway and Switzerland (1.3 % each) come close to these levels.

In addition, the nature of public funding for education varies considerably across countries and time. Most countries fund on the basis of inputs such as number of enrolled students (Australia, Belgium, France, and New Zealand). Funding in Denmark stresses output, since universities receive funding on number of grade points that students receive (the ‘taxi-meter model’). The Netherlands and Sweden take intermediate positions. About half of funding in the Netherlands depends on the number of diplomas. A similar share of resources depends on number of grade points in Sweden. Germany and the UK differ as funds are allocated on historical grounds independently of the number of students or output criteria, but funding is based on negotiations and enrolment forecasts. However, the UK government puts a growing emphasis on output and performance in teaching and research.

Private investment in higher education in the EU amounts to less than 0.2 % of GDP compared to a weighted OECD average of 0.9 %. Private investment in higher education in the US is more than ten times higher (1.8 % of GDP) and in Japan about four times higher (0.6 %) than in the EU. Even in the three leading EU countries – Spain, the Netherlands and the UK (0.3 % each) – private investment in higher education is only one third of the OECD average. The OECD country with the highest private spending on higher education is Korea (2.3 %).

The differences in the level of private investment are a result of differences in tuition fees (most EU countries do not have tuition fees), in the share of private institutions, in philanthropic funding and in the level of funding provided by enterprises. No tuition fees exist in Denmark, Germany and Sweden. Other countries have fixed but positive tuition fees that may differ between various fields of study (Australia, France, Netherlands, and the UK). Typically, prices charged to students do not depend on costs. In recent years, governments (Australia, Belgium, France, Netherlands and UK) increased tuition rates to maintain resources per student in the face of increasing enrolment. This also happened in the US and New Zealand where institutions are free to set fees. Some countries (Belgium, Netherlands, UK) have decreased student grants and increased loan facilities. In contrast, Germany, Sweden and Denmark, have increased grants and loan facilities. France only increased grants. Conditions governing student grants have become tighter in some countries by linking grants/ loans to academic progress (Denmark, Germany, Netherlands, and Sweden).

2. Funding on research in higher education

a. No clear evidence of underfunding of research at higher education institutes compared to the US

Table 15 presents comparative figures on types of spending on R&D. R&D performed in the higher education sector is on the rise in Europe, Japan and the US. In 2004, higher education expenditure on R&D amounted to 0.40 % of GDP in the EU as a whole, above its 1997 level (0.38 % of GDP). Within the EU, the three Nordic countries Sweden, Finland and Denmark showed the highest intensity of higher education R&D, with values above 0.60 % of GDP. In the US, higher education expenditure on R&D amounted to 0.36 % of GDP in 2003, similar to the 1997 rate [11].

The overall R&D deficit of the EU (1.8 %) with respect to the US (2.7 %) and Japan (3.1 %) is mostly due to the private sector. This is why the share of universities in total R&D expenditures is much higher in the EU than in the US. Surprisingly, business support for R&D in the higher education sector is higher in the EU (6.5 %) than in the US (5.5 %), and in Japan (2.6 %).

[11] While the overall size of R&D funding for the higher education sector in EU does not compare badly with respect to the US, there are marked differences between the EU and the US in who allocates funds and in which way. The US funding system is based more on competition. Unfortunately, it is hard to document with hard data.

Table 15 Spending on research in higher education

US	*JAP*	*EU-25*	*FIN*	*DK*	*SE*	*UK*	*GER*	*FRA*
Expenditures on R&D by higher education sector, as % of GDP								
0.36	0.42	*0.40**	0.69	0.61	0.87*	0.40*	0.41	0.41
Total expenditures on R&D as % of GDP (2004)								
2.68	3.13	*1.81**	3.51	2.48	3.95*	1.88*	3.13	2.16
Share of higher education sector in total R&D								
13.6	13.4	*22.1**	19.8	24.4	22.0*	21.4*	16.3	19.1
Higher education sector R&D financed by industry								
5.0	2.8	*6.5**	5.8	3.0	5.5*	5.5*	12.8	2.7*

Data are for 2004, unless * (=2003).
Source: OECD, STI indicators 2007.

3. *Summing up*

— Total investment in higher education in the EU is below the level of key competitors. In particular, funding per student is almost half the level of that in the US.
— The nature of public funding for education varies considerably across countries and time, where the Scandinavian countries have relatively high funding.
— Differences across countries in spending become even more pronounced if the public versus private source in this funding is considered. The gap in private funding is particularly important.
— The differences in levels of private investment are a result of differences in tuition fees (most EU countries do not have tuition fees), in the share of private institutions, in philanthropic funding, contributions by alumni and in the level of funding provided by enterprises. This is why US universities are much better funded than their EU counterparts.
— There is no clear statistical evidence supporting less funding of research at higher education institutes in the EU as compared to the US, although the way most of the research funding in the US is allocated may be different.

B. University governance

Universities are not just collections of individuals as teachers and/or researchers. But they also exist as *institutions* within the research landscape, with university leadership setting out the missions, strategic goals and structures in which their staff operate and interact with their environment. University governance systems can be characterised across countries along two important dimensions: (i) *autonomy* and (ii) *accountability*. Autonomy captures the extent to which institutions are free to manage their resources and to shape their activities. Accountable systems provide incentives by allocating resources on a performance basis and by evaluating outcomes. Unfortunately there is little data available to characterise and internationally compare the governance structure of universities. The OECD (2007) has developed a series of indicators bases in its surveys of its member countries measuring autonomy (financial autonomy, staff policy autonomy with respect to hiring/firing and wages, student selection and course content) and accountability (evaluation mechanisms and funding rules). A summary of these indicators in presented in Table 16.

Table 16 Governance characteristics of universities in OECD countries

	US	*JAP*	*UK*	*SE*	*DK*	*FIN*	*GER*	*FRA*	*ES*	*IT*
Autonomy										
Selection of students	7.8	6.6	6.7	8.9	7.0	7.1	2.8	2.8	10	3.7
Budget flexibility	8.5	8.2	6.8	6.2	6.2	7.7	7.2	6.8	7.9	7.0
Staff policy flexibility	10	10	10	10	10	7.5	7.5	1.8	4.9	7.9
Hiring/Firing	10	10	10	10	10	10	10	0.9	3.8	10*
Wage/ non-wage conditions	10	10	10	10	10	5	5	2.7	5.9	5.7
Course content	10	10	10	5.5	10	10	5.5	10	10	5.5
Accountability										
Evaluation mechanisms	6.6	6.2	7.7	6.5	4.6	4.0	6.9	5.6	6.5	6.8
Funding rules	3.6	3.9	5.5	4.6	5.3	6.2	5.2	6.6	4.8	5.9

Source: Oliveira Martins *et al.*, OECD (2007).
Note: Based on survey of official regulations in the different EU countries (OECD, 2007).

The US has the highest scores on all dimensions of autonomy. In Europe, the better performing countries, i.e., UK, Finland, Sweden and Denmark, also score high on autonomy, although there are some differences depending on the type of autonomy. On accountability, there is much more variance among the well performing countries with the UK high on both dimensions of accountability while the US (like Japan) is low on financial accountability (consistent with their high budget flexibility). Finland is high on financial accountability, but not too strong on evaluations.

Among the continental weak performers, France, Germany, Spain and Italy, there is also a large dispersion in governance characteristics. The common theme, nevertheless, seems to be low levels of autonomy, but relatively high levels of accountability. This is consistent with the complaint of overregulation in these systems. Nevertheless, the dimensions of (lack of) autonomy are different, with Germany and Italy particularly restricted with respect to students, course contents and wages, France on selection of students and both hiring and wages, Spain restricted in both hiring and wages. The following Box further details the status and trends in governance in EU countries.

Also, the Brueghel study (Aghion *et al.,* 2007) reports scores on various dimensions of autonomy, on the basis of survey responses from universities appearing in the Shanghai ranking, for a number of European countries (excluding US and France, but including Switzerland). Apart from budget autonomy, hiring autonomy and wage-setting autonomy, the figures reported in Table 17 also include a measure of ownership of universities (public versus private). In most countries, universities are publicly owned[12]. Only the UK has most private universities. On autonomy,

[12] Belgium scores average on public ownership, but most of its private universities rely nevertheless mostly on public funding and are therefore subject to similar public control as their publicly owned peers.

Box: Trends and status of governance in higher education in the EU

The majority of countries are implementing or in the process of introducing reforms of higher education. There is no predominant model for higher education governance in Europe: diversity remains the hallmark of European higher education. Although concrete policy actions vary from country to country, there are some common themes: increasing public funding for higher education, granting autonomy to institutions in the management of financial resources, promoting the direct link between results and the amount of public funding allocated, and encouraging the diversification of funding sources and creation of partnership with business.

In most countries, HEIs have an advisory or supervisory body that includes or is composed solely of external stakeholders. But these bodies have often limited strategic planning responsibility. In about two-thirds of the countries in Europe the responsibility for goal setting and strategic planning is undertaking by governance bodies composed solely of internal stakeholders.

Autonomy in terms of financial management is a key trend. Only five countries in the EU remain with strict financial controls per budget heading. Elsewhere, block grants exists, with serious autonomy on how to spend grants. In seven countries (including Denmark and France) a significant amount of public funding is associated with a performance contract. Nevertheless, whether or not the qualitative objectives included in these contracts are met, has still little influence on the amount of funding allocated in the following contract, for the moment. Almost all European countries use standarised funding formulas for the allocation of public funds. The use of performance indicators is becoming increasingly common. Most of the time, this includes the number of students enrolled at an institution and research activities. However, in most countries, only a small proportion of funds are allocated on performance indicators. In Italy and Ireland for example, performance is taken into account for a maximum of 5 %. The UK (England) is indisputably one of the countries where the amount of funding allocated to institutions depends most on their performance in terms of students' results and the quality of research. In Denmark funding for teaching depends only on students' results.

Public funds for research are allocated via various mechanisms. All countries have at least part of these funds allocated on a competitive basis for specific research projects and programs, next to basic research grants. The calculation of these basic grants varies markedly across countries. In the Flemish Community of Belgium, publications and citations count for an increasing share of basic funding for research. The vast majority of European countries have implemented incentives to support higher education institutions in their search for private funding and in developing partnerships with the private sectors, with tax allowances for donors the most common. Only in the Flemish Community of Belgium, France, Finland, Sweden and the UK, a regulatory framework exists which authorises institutions to own the intellectual property rights of the results of research conducted by their staff and allowing institutions to create companies and supporting partnerships with the private sector in the area of research.

A common neglect in the reform process, are the policies concerning academic staff. Only very few countries are working on reforms to provide institutions with more room to manœuvre in terms of staff. The Netherlands and the UK have a high level of autonomy through the whole process of recruitment of personnel. In most countries at least parts of the process are regulated or supervised. Also, in terms of salaries and promotions, regulation and supervision are common. Another common weak point is the lack of professional management experience on the part of academic experts in senior-level positions. The authority of the Chief Executive has been reinforced in many countries. Although academic competences continue to be the main qualification for this post, managerial expertise and leadership skills are considered important assets.

Note: Based on survey of official regulations in the different EU countries (OECD, 2007).

the results confirm the OECD data, with a large heterogeneity among countries[13]. Switzerland, not in the OECD list, but one of the top performing countries, has a high autonomy with respect to hiring, but not on budgets and wages. Among the

[13] The divergence in Italy's score on hiring policy can be explained, beyond measurement errors, by differences in time period and sampling methodology (official procedures and perceived impact of procedures).

three European countries with the best performance index, the practice of appointing people from within the own group (‘endogamy’) is high in Sweden but low in Switzerland and the UK. Swedish and UK universities can set wages but Swiss cannot, and universities are mostly public in Sweden and Switzerland whereas they are mostly private in the UK. They also found a high degree of heterogeneity between countries in terms of size of universities in the Top-500: Southern Europe (Italy and Spain) has very large (more than 40,000 students on average) universities, while the UK and Switzerland have small (10-15,000 students) universities.

Table 17 Governance characteristics of European universities

	Public Status	*Budget autonomy*	*Hiring autonomy*	*Wage-setting autonomy*
Belgium	0.5	0.4	1.0	0.0
Denmark	1.0	1.0	0.5	0.5
Germany	0.9	0.0	0.8	0.0
Italy	1.0	0.9	0.4	0.0
Netherlands	0.8	0.8	0.8	0.2
Spain	1.0	0.5	0.5	0.0
Sweden	0.8	0.1	0.8	0.0
Switzerland	0.8	0.1	0.8	0.0
UK	0.5	0.9	1.0	0.8

Source: Bruegel survey, Bruegel Policy Brief, Aghion *et al.* (2007).

C. *Linking governance to performance*

Section 3, B, has documented the high variance in university governance across countries. There are also a lot of differences in different dimensions of governance across countries. Furthermore, different dimensions of autonomy and accountability not necessarily correlated. As a consequence, each system can be characterised as a relatively unique bundle of governance characteristics.

All this makes governance a very interesting candidate to consider for explaining the heterogeneity in performance of European universities. Nevertheless, since both the least performing countries show a wide divergence in governance, as well as the best performing systems, a crude bird’s eye view already suggests that the link between governance and performance will be complex and bodes badly for the quest for a unique optimal governance model.

The Bruegel study (PB2007) reports some first interesting findings on the relationship between their set of proxies for governance and research performance, as measured by the Shanghai ranking of their set of surveyed universities. First, these results indicate that it is important to correct for other determining factors, besides governance. Size, age and budget per student all positively affect research performance. But once these factors are included, the only governance indicator that turns out to be significant is budget autonomy. Perhaps, the most important finding of the study is that the positive effects of having larger budgets per student are higher when the institutes enjoy a higher degree of budget autonomy, suggesting policy should tackle simultaneously funding and governance. But clearly, more research is needed to pin down the drivers of university performance. At this stage, the most important conclusion that can be drawn from the available evidence is that more research is needed to pin down the drivers of university performance. Nevertheless, a few policy implications for the reform agenda might be put forward.

4. The policy agenda for higher education reform in Europe

The previous analysis has shown that the EU needs to improve its access to higher education, improve its higher education attainment levels and the quality of its education and research. For this it needs to increase total investment in higher education and research. Funding universities will become increasingly more challenging due to the relentless operation of Baumol's cost disease. Productivity growth in universities inevitably lags behind that in manufacturing, so the cost and price of university education inevitably rise over time. This is Baumol's cost disease applied to higher education (e.g., Jacobs and van der Ploeg, 2006). On the plus side, the ongoing technical progress in the rest of the economy makes society much richer all the time and it is thus able to afford the escalating costs of higher education. Teaching and research need to be done by highly qualified people and is difficult to be replaced by technology.

If the EU has to make an effort to bridge its funding gap, be it public or private, this can only be realised if at the same time the *governance* of universities is tackled. This is necessary to increase the efficiency of spending by these organizations, thereby delivering results. To attract more *funding*, universities first need to convince stakeholders – governments, companies, tax payers and above all students – that existing resources are efficiently used and would produce added value for them. Higher funding cannot be justified without profound change. Providing for such change is the main justification and prime purpose for fresh investments.

A. Increasing total investment in higher education

While public investment in higher education in the EU is at the same level or even slightly higher than in key competitor countries, levels of private investment are clearly lower. A major effort will be needed to locate the necessary public and private financial resources to bring the EU countries closer to the standards of key competitors.

The debate on social and private returns from higher education has highlighted its role as an investment, benefiting both the individual as well as society as a whole. If *social returns* exceed private returns, education causes positive external effects to society and the government should support education. Although positive external effects may be substantially larger for secondary and especially primary education, they are nevertheless likely to prevail also for certain types of university education. For basic research, the public good characteristic is well known.

But beyond the need for a sufficiently large *public investment* in universities, there is also an issue of *how* to best invest public money. Governments should strike the right balance between core, competitive and outcome-based funding (underpinned by robust quality assurance) for higher education and university-based research. Competitive funding should be based on institutional evaluation systems and on diversified performance indicators with clearly defined targets and indicators supported by international benchmarking for both inputs and economic and societal outputs. Funding should be based on less malleable criteria.

Beyond the case for public spending, the empirical evidence suggests that *private returns* to higher education are substantial, also in continental Europe[14]. All this evidence suggests more scope for *private funding* of higher education and in particular for asking students to pay higher tuition fees, particularly for those degrees where private returns are substantial. With the private and social returns differing across the various types of higher education (Bachelor, Master, Ph.D. and across disciplines), the private versus public funding share can also be differentiated (Aghion *et al.*, 2007).

Free higher education does not by itself suffice to guarantee equal access and maximum enrolments. This casts the much debated issue of higher tuition fees in a fresh perspective, isolated from the discussion on access, which is better targeted through other instruments, such as income-contingent loans and scholarships for the brightest students from backgrounds with not much money. The experience with social credits in the form of an income-contingent loan system of the type used in Australia suggests that this need not jeopardise accessibility of higher education (Barr and Crawford, 2005; Jacobs and van der Ploeg, 2006). Since peer effects are important in higher education, it is crucial to attract the best students regardless of background. Europe would therefore benefit from shifting attention from scholarships for the poor to scholarships for the brightest regardless of background.

And to mobilise more private funding from industry for research, a clear regulatory framework would need to be put in place.

B. Improving governance

At this stage there is relatively little hard data and analysis on the link between governance and performance, and the evidence not in favour of a unique optimal model. Hence, European policy makers should be careful not to impose a standardised, micro-managed governance model on their universities. While it could be argued that society through its government could enforce a number of objectives on universities (e.g., with respect to selection of students or curriculum design) in return for public funding, but beyond this universities should be given sufficient degree of freedom to develop their own strategies. The government should rather try to nurture the heterogeneity of its institutions, allow for experimentation and learn from it. This calls for granting universities the space and thrust to develop autonomously their own strategies and structures.

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[14] Canada is an interesting testing ground, since provinces levy different fees. Evidence suggests that rising fees by about 2,000 dollars in the 1990s reduced the probability of participation by persons aged 17, 18 and 19 relative to trend by amount 2 %-points. Nevertheless, university participation increased dramatically during this period (Johnson and Rahman, 2005). Unfortunately, this interesting study did not take account of factors like family income or parental education.

Public authorities should guide the university sector as a whole through a framework of general rules, policy objectives, funding mechanisms and incentives for education, research and innovation activities. In this way they can develop their own strategy, specialization and structures to respond to their heterogeneous environments. While some progress has been made in some countries on financial autonomy, in the area of staff policy, the restrictions on hiring and wage-setting are still, despite reforms, too restrictive, especially in continental Europe. Universities will not become innovative and responsive to change unless they are given real autonomy on pivotal instruments.

In return for being freed from the stifling blanket of over-regulation and micromanagement, universities should accept full *institutional* accountability to society at large for their results. In many countries this would mean a new approach to policy making with less *ex ante* checks and greater *ex post* accountability of universities for quality, efficiency and the achievement of agreed objectives. For universities, this requires new internal governance systems based on strategic priorities and on professional management of human resources, investment and administrative procedures. A pivotal area of university management is personnel management. Human resources are a core determinant of quality in higher education and research. Universities must therefore work to enhance their human potential, both qualitatively and quantitatively, by attracting, developing and keeping talent in the teaching/research career. Excellence can only emerge from a favourable professional environment based in particular on open and transparent procedures.

C. More competition among universities

Public and private stakeholders should provide the funds for universities to develop their own structures while holding them accountable for delivering results. Yet combined under-funding and system rigidities are so acute in some countries of the EU that they impede the reform process at universities, who are consequently trapped in a vicious circle.

To unlock the reform process, perhaps the most important driving force for modernizing higher education in Europe emerges from competition. Increased competition for students, faculty and funding, combined with more mobility of students and faculty and allocation of resources through open, competitive criteria, will lead universities to offer a more open and challenging environment to the most talented students and researchers, thereby making them more attractive to Europeans and non-Europeans alike. The competitive arena for universities will only be a forceful driver of change if it is of a sufficiently wide international level. Universities operating in segmented local markets will not have sufficient incentives to rise to the global challenges.

In response to scarcer public budgets, a rationalisation of the supply side of the higher education market has taken place in Europe. The resulting increase in the scale of universities has, however, generated the danger of creating (local) public monopolies. In the Netherlands the rapid increases in scale and monopolistic practices have gone hand in hand with huge increases in overhead and capital expenditures leading to substantial falls in resources for teaching. Such monopolies reduce quality ('grade inflation'), ignore demand of students and employers, and increase overhead costs. Monopolistic price setting drives up tuition fees and lowers quantity and quality of supply of education, especially if the price elasticity of demand is low.

Competition for talents and brains is a global game, which is already removing the barriers within Europe and establishing a large, integrated market for higher education and research in Europe. This will provide an excellent environment for European universities to develop their comparative advantages and make them stronger players on the world scene.

5. Mobilising support for higher education reform

A. Tasks for stakeholders

Implementing this necessary restructuring and modernisation of higher education systems in Europe requires coordinated action from all parties involved:

— *Public policy makers* need to take the necessary measures with respect to universities, including aspects such as management, granting real autonomy and accountability to universities, funding mix and access to higher education. Funding should be based less on inputs or outputs and more on academic excellence. They should also allow universities to set fees independently and to differentiate them by type of student and type of course. They should provide student with income-contingent loans and cover default out of general funds.

— The *European Commission* can contribute perhaps most importantly through improving the conditions for competition among universities to take place at international level. An internal market for higher education and research: the European Research and Higher Education Area should improve the mobility of students, researchers and funds. It also has a role in supporting the reform process, by promoting policy dialogue and mutual learning, through financial support to Member States and to universities in their modernisation activities. The Commission can also take the lead in developing and implementing a set of quality indicators for institutions in the EU according to a multitude of criteria. They may also engender transparency of the EU market for higher education and to take action to demolish the power of monopolistic universities if it is used to the detriment of students. And the European Investment Bank can assist in offering income-contingent loans to students.

— *Universities*, for their part, need to make strategic choices and conduct internal reforms to extend their funding base, attract the best students and faculty, enhance their areas of excellence and develop their competitive position. They should clearly state their mission and act accordingly. A wider differentiation of objectives should be allowed to arise, with institutions specializing in research or undergraduate, graduate or post-graduate education. In any case, they must aim to compete with the best institutions elsewhere in the world, if their objective is to pursue excellence.

— *Students* should adopt a different mindset and choose the degree programme that best suits their needs. Clearly, this need not be the university closest to their family home and may well be a top university abroad. They also need to fund a greater part of their own education and thus be encouraged to demand the highest quality.

— *Faculty* need to be supportive of the change process, being responsive to the new strategies and structures of their universities, and at some instances, even instigating changes. By being more mobile and selecting the best universities to work for, they will provide a strong incentive for universities, competing to attract the best of talents, to change their strategies and structures accordingly. Faculty need to be aware that they are accountable towards their employers, funders or other related public or private bodies as well as, on more ethical grounds, towards society as a whole, for the efficient use of public and private money spent on them.

— *Industry* should be providing more funding for the private benefits they get out of universities. At the same time, they can become more actively involved in the reform process, while nevertheless respecting universities' autonomy and specificities.

How likely is it that all of these stakeholders can be mobilised in the reform process? And how strong will be the support for the details of the reform agenda? Some of the aspects of reform (e.g., higher tuition fees, student selection or more private sponsoring) may be very controversial in some countries among stakeholders and the public at large.

B. Perspectives of stakeholders on the reform process

The European Commission carried out in February 2007 a Flash Eurobarometer Survey, interviewing almost 6,000 randomly selected faculty of universities across all 27 Member States on their opinions of the higher education reform process in their countries[15]. The main results are reported in Tables 18 and 19. Although faculty are only one part of the stakeholders involved, they are nevertheless pivotal as they are the ones who have to deliver the education and research services for the knowledge-based society.

1. Confidence in the involvement of stakeholders in the reform

Surprisingly (or not), faculty seem to have most confidence in their own university leadership (and even more in their own faculty leadership). This could be considered as good news, since this reflects a healthy level of trust inside universities, which is needed to deal with changes. However, this could also be reflecting a common coalition against change, which is bad news if it is concentrated in the bad performing systems. The least confidence is enjoyed by the private sector. But also national or regional authorities score low on confidence. This is particularly worrisome as this is the level of public policy competence that is most relevant for instigating the reforms.

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[15] This represents about 5 % of total number of faculty in higher education institutions. For most of the reported EU-15 countries the number of observations are at least 200. The exception is Greece, with a low response rate (N = 56), which makes the Greek results very fragile.

The survey results reveal an interesting divergence across Member States in opinions (the tables only report the outlier EU-15 countries). Trust in university leadership is particularly low in France, a country where changes to the system are high on the policy agenda. On the other extreme, i.e., Italy and Greece, have an above average trust in their university leaderships' involvement in reforms. Hopefully this supports the right direction of change. On the contrary, Greeks have very little confidence in the involvement of their politicians. The UK is also an interesting case with faculty having a below average confidence, both in their university leadership and their politicians.

Table 18a Confidence in the stakeholders of the reform process

	Full confidence	*Some confidence*	*No confidence at all*	*DK/NA*
Your own faculty	59 %	34 %	4 %	3 %
University leadership	42 %	44 %	7 %	6 %
National university association	34 %	49 %	9 %	7 %
European university association	22 %	50 %	15 %	14 %
Professional association	18 %	56 %	19 %	6 %
European Commission	17 %	51 %	26 %	6 %
National or regional authorities	12 %	64 %	19 %	5 %
Private enterprises	9 %	52 %	32 %	7 %

Table 18b Involvement of university leadership in reforms: % full confidence

GR	*AT*	*IT*	*FI*	*EU-27*	*DK*	*PT*	*BE*	*IE*	*UK*	*FR*
52 %	50 %	50 %	49 %	*42 %*	36 %	32 %	29 %	24 %	18 %	14 %

Table 18c Involvement of national or regional authorities in reforms: % no confidence

DK	*FI,SE*	*BE*	*PT*	*IT*	*NL*	*EU-27*	*AT*	*DE*	*UK*	*GR*
5 %	8 %	12 %	13 %	15 %	16 %	*19 %*	21 %	21 %	22 %	46 %

Table 18d Confidence levels by faculty characteristics

	Total	*Young*	*Rector/Deans*	*Economics*
% full confidence in university leadership	42 %	39 %	48* %	40 %
% no confidence in national/regional authorities	19 %	15 %	22 %	17 %

Source: Eurobarometer 198 on Higher Education Reform, The Gallup Organisation.

The data also allow differentiating the results according to individual characteristics of the faculty like age, gender, position, field, experience and type of institution[16]. But no strong differences emerge on these dimensions. Interestingly for the political economy of the reform process, deans seem to have an even stronger confidence in their rector and board than the average faculty. This suggests even stronger consensus inside the university leadership than between the university leadership and their faculty.

2. Support for the reform agenda item

The Eurobarometer also surveys the perceptions of faculty on two major issues of the reform agenda: funding and governance – see Table 19. The most contentious issues seem to be the private/public funding mix, the effects of more competition among universities, and student fees. There is relatively little disagreement among teaching professionals on the improvement of the internal governance of their university and neither on the issue of student selection.

Table 19a Support for the reform agenda items

	% disagree	*% agree*	*% DK/NA*
1. Universities should be allowed to select and refuse students	13 %	83 %	4 %
2.1. Universities should be publicly funded and not seek more private funding	40 %	53 %	7 %
2.2. More private funding would help universities to gain extra income and perform better	22 %	73 %	6 %
2.3. Student fees are acceptable as a source of extra income for universities	26 %	68 %	6 %
3.1. Universities need more autonomy from public authorities	19 %	75 %	6 %
3.2. Partnerships with business will reinforce universities	21 %	73 %	6 %
3.3. Universities are in need of better internal management	12 %	80 %	9 %
4. Competition between universities will improve quality	28 %	68 %	4 %

[16] The sample of teaching professionals surveyed includes 28 % females, 18 % younger than 40, 21 % rector and deans, 53 % full professor, 12 % in economics&business, 44 % in the hard sciences, 16 % with more than 30 years of teaching experience and 61 % from institutes that offer all degrees (bachelor, master, Ph. D.).

Table 19b Support for the reform agenda items by faculty characteristics (% disagree)

	Total	*Young*	*Rector/Deans*	*Economics*
1. Universities should be allowed to select and refuse students	13 %	17 %	10 %	9 %
2.1. Universities should be publicly funded and not seek more private funding	40 %	46 %	42 %	44 %
2.3. Student fees are acceptable as a source of extra income for universities	26 %	30 %	18 %	14 %
3.1. Universities need more autonomy from public authorities	19 %	20 %	14 %	17 %
3.3. Universities are in need of better internal management	12 %	12 %	11 %	11 %
4. Competition between universities will lead to improvement of quality	28 %	32 %	22 %	22 %

Source: Eurobarometer 198 on Higher Education Reform, The Gallup Organisation.

Again, there are no strong differences across individual characteristics. Economics faculty members are more supportive of selection and student fees and somewhat more supportive of competition than other faculty members, although on the competition item the strongest support comes from the hard sciences. Rectors and deans are somewhat more supportive of autonomy, not surprisingly, but also of student selection and charging student fees. They favour somewhat less competition.

However, when differentiating according to countries, the results show again wide country heterogeneity on a number of issues. The divergence in opinions across countries can be explained by differences in the current performance of the higher education system and the process of reforms currently going in the country. But they might also reflect differences in preferences.

On the issue of student selection, there is a widespread divergence across countries. For example, student selection is no issue of disagreement in the UK and Finland, almost no issue in Germany, but in Sweden and Belgium it is a contentious issue. Similarly, for charging student fees there are large differences across countries, with especially the Nordic countries (Finland, Sweden, Denmark) strongly against. The issue of a larger share of private funding splits opinions everywhere. Support for public funding is highest in the UK, Sweden and Austria while more private funding is most supported in Spain.

Table 19 Support for the reform agenda items, by country (% disagree)

1. Universities should be allowed to select and refuse students										
UK	*FI*	*DE*	*EU-27*	*NL*	*FR*	*AT*	*IT*	*ES*	*SE*	*BE*
1.6%	2.5%	8.3%	*13%*	17.3%	19.2%	19.5%	21.5%	21.9%	32%	38%

2.1. Universities should be publicly funded and not seek more private funding								
UK	*AT*	*SE*	*DK*	*DE*	*EU-27*	*IT*	*FR*	*ES*
24%	26.5%	26.9%	27.5%	32.3%	*40%*	42.4%	45.2%	59.2%

2.3. Student fees are acceptable as a source of extra income for universities									
ES	*DE*	*EU-27*	*BE*	*FR*	*UK*	*GR*	*FI*	*SE*	*DK*
18.6%	23.1%	*26%*	27.6%	28.8%	34%	46.5%	58.4%	62.3%	66.7%

3.1. Universities need more autonomy from public authorities										
GR	*DE*	*PT*	*EU-27*	*IE*	*BE*	*NL*	*ES*	*AT*	*FR*	*IT*
5.4%	12.7%	14.3%	*19%*	18.8%	20.7%	21.5%	21.9%	25%	26.4%	26.6%

3.3. Universities are in need of better internal management										
GR	*IT*	*ES*	*PT*	*EU-27*	*DK*	*FR*	*SE*	*BE*	*UK*	*NL*
1.8%	3.6%	4.2%	7.5%	*12%*	15.2%	16.4%	16.5%	20.7%	22.4%	27.7%

4. Competition between universities will lead to improvement of quality										
PT	*ES*	*DE*	*EU-27*	*FI, IT, SE*	*NL*	*BE*	*IE*	*DK*	*FR*	*UK*
18.8%	19.2%	27%	*28%*	28%	37.4%	40.9%	41.6%	42.6%	45.6%	48%

Source: Eurobarometer 198 on Higher Education Reform, The Gallup Organisation.

On the need for more autonomy for universities, there is less divergence across countries. In most countries there is a strong support for more autonomy, as is the need for better governance structures. This holds especially in the Southern countries (Italy, Spain, Portugal and Greece), which are also in need of better governance structures. Unfortunately the Eurobarometer did not go into the details of the governance issue, on types of autonomy and management practices. On these details, opinions might be more heterogeneous.

Another splitting issue across and within counties is the support for more competition among universities. On the impact of competition on quality, opinions are spilt in France, but also in the UK, the country which perhaps has been the most exposed to competition. Support for competition is larger in Portugal and Spain.

6. Challenges for research into the economics of higher education reform

Universities are key players in the successful transition to a knowledge-based economy and society. However, this crucial sector of society needs restructuring if Europe is not to lose out in the global competition in education, research and innovation.

We have argued that, while EU universities have improved their quantitative performance with respect of the number of graduates and publications, it needs to further increase higher education attainment levels and improve the quality of its research. We have also highlighted the problems European universities face on governance and on the size and the nature of their funding. The link between governance and performance is not obvious and needs still further data and research. Also the (inter)linkages between governance, funding and other performance determining factors need further research, preferably also bringing in historical and cultural factors. Differences in perspectives on reforms abound in the EU, across countries, predicting a heterogeneous process and outcome of reforms. But also within countries, there are items on the reform agenda which are contentious, which may lead one to predict a difficult political economy process of reforms even though inside universities trust levels are high.

All this implies that we know as yet very little on what the best governance and funding structure should be. Perhaps the most important conclusion for policy making at this stage is to invest more in data & analysis to support a more evidence-based reform process aided by experimentation and evaluation.

Nevertheless, the preliminary evidence so far seems to suggest that society supports a multitude of university structures to respond to a heterogeneous set of preferences. This calls for granting universities the space and trust to develop autonomously their own strategies and structures. Public and private stakeholders should provide the funds for universities to develop their agenda while holding them accountable for delivering results. Increased funding cannot be justified without profound change. Providing for such change is the main justification and prime purpose for fresh investments. Yet combined under-funding and system rigidities are so acute in some countries of the EU that they impede the reform process at universities, who are consequently trapped in a vicious circle.

If countries are to break this vicious circle, they need to combine more and better targeted funding simultaneously with reforms of the supply side, thus creating the necessary conditions to enable universities to improve their performance, to modernise themselves. Probably, the most important driving force for instigating change in the system and break the vicious circle is competition for students, faculty and funding. While this competition eventually will take place on a global scale, the removal of barriers within Europe, thereby establishing a large, integrated market for higher education and research in Europe, would provide an environment for European universities to develop their comparative advantages. This would enable and encourage them to become stronger players on the world scene.

Within a more integrated European Higher Education Area, universities are able to build on their own strengths and differentiate their activities on the basis of these strengths. While institutions share certain common values and tasks, not all of them need the same balance between education and research, the same approach to research and research training, or the same mix of services and academic disciplines. This would allow the emergence of an articulated system comprising world-renowned research institutions, plus networks of excellent national and regional universities and colleges which provide shorter specialised education. Such a system would mobilise the substantial pool of knowledge, talent and energy within universities and would merit – and be in a position to generate – the increased investments needed to make it compete with the best in the world.

References

AGHION P. (2006), *A primer on innovation and growth*, Bruegel Policy Brief, 6, 1-8.

ALESINA A. and E. SPOLAORE (2003), *The Size of Nations*, MIT Press, Cambridge, MA.

AGHION P., M. DEWATRIPONT, C. HOXBY, A. MAS-COLELL and A. SAPIR (2007), *Why reform Europe's Universities?*, Bruegel Policy Brief, Brussels (*infra*, in this volume).

BARR N. and I. CRAWFORD (2005), *Financing Higher Education*, Routledge, London.

BOARINI R., J.O. MARTINS, H. STRAUSS, C. DE LA MAISONNEUVE and G. NICOLETTI (2008), Investment in tertiary education: Main determinants and implications for policy, *CESifo Economic Studies*, Special issue, 52(3).

JACOBS B. and F. VAN DER PLOEG (2006), "Guide to reform of higher education: A European perspective", *Economic Policy*, 47, pp. 535-592.

JOHNSON D.R. and F.T. RAHMAN (2005), "The role of economic factors, including the level of tuition, in individual university participation decisions in Canada", *The Canadian Journal of Higher Education*, XXXV(3), pp. 101-127.

SIANESI B. and J. VAN REENEN (2003), "Education and Growth: a review of the literature", *Journal of Economic Literature*, 17(2), pp. 157-200.

STEPHAN P. (1996), "The economics of science", *Journal of Economic Literature*, XXXIV, pp. 1199-1235.

THISSEN L. and S. EDERVEEN (2006), Higher education: time for coordination on a European level, Discussion Paper No. 68, CPB Netherlands Bureau for Economic Policy Analysis, The Hague.

VAN DER PLOEG F. and R. VEUGELERS (2008), "Towards evidence-based reform of European universities?", *CESifo Economic Studies*, Special issue, 52(3), pp. 2-22.

Why reform Europe's universities?

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Summary

Recently published international rankings indicate that the performance gap between European and American universities is large and, in particular, that the best European universities lag far behind the best American universities. The country performance index we construct using the Shanghai ranking confirms that despite the good performance of some countries, Europe as a whole trails the US by a wide margin. The reason for this situation, which contributes to Europe's lagging growth performance, is two-fold. First, Europe invests too little in higher education. Total public and private spending on higher education in EU25 accounts for barely 1.3 % of GDP, against 3.3 % in the US. This translates into average spending of less than €10,000 per student in EU25 versus more than €35,000 in the US. Second, European universities suffer from poor governance, insufficient autonomy and often perverse incentives. We show that both factors contribute to the EU's poor performance and that reform should take place on both fronts, because autonomy also increases the efficiency of spending.

1. Introduction

European growth has been disappointing for the last 30 years but policymakers have only recently started to realize that Europe's growth performance is intimately linked with the research performance of its universities.

Europe invests too little in higher education. It is by now widely known that the European Union (EU) spends less than two percent of its GDP on R&D, compared to more than 2.5 percent in the United States (US). But the gap between Europe and the US is even wider for universities than for R&D spending. In 2001, total (public and private) spending on higher education in EU25 accounted for barely 1.3 % of GDP, against 3.3 % in the US. In other words, Europe spends every year two percent

[1] This article was published as a *Bruegel Policy Brief*, issue 2007/04, September 2007, © Bruegel. We are very grateful to Aida Caldera, Indhira Santos and Alexis Walckiers for their excellent research assistance, and to colleagues across European universities in helping with the university survey used in this policy brief.

of GDP less than the US. In terms of expenditure per student, the contrast is starker still, with an annual spending of €8,700 in EU25 versus €36,500 in the US.

But the unsatisfactory research performance of Europe's universities also results from inadequate institutions. European universities suffer from poor governance, insufficient autonomy and often perverse incentives.

Europe started to recognize some years ago that its university system faces a problem. A first step was the Bologna Declaration that initiated the creation of a "European Higher Education Area". Recently, a growing number of individual EU member states have introduced reforms of their university systems.

However only the recent publication of global rankings, such as the Shanghai Jiao Tong University Academic Ranking of World Universities (the "Shanghai ranking") has made most policymakers aware of the magnitude of the problem and sparked a public debate on university reform. These rankings tend to reinforce the evidence that the US is well ahead of Europe in terms of cutting-edge university research.

The purpose of this Policy Brief is to examine what reforms are needed in order to enable European universities to produce world-class research and thus make the optimum contribution to growth[2].

In the first section of this Brief, we draw conclusions from the Shanghai ranking both about European university research performance in relation to that of US institutions and about differences in performance between European countries. We then report on our own survey of European universities listed in the Shanghai ranking, which we use to establish what determines university research performance. We also use comprehensive US data to analyse the interplay between autonomy and funding in boosting university research performance. Finally, we make concrete proposals about how to improve the conditions for research at European universities with the objective of boosting their contribution to growth.

2. Country performance

The debate on the funding and governance of European universities has been stirred greatly by the publication, since 2003, of the so-called Shanghai index which measures university research performance. Constructed by a group of Chinese scholars, the Shanghai index is a weighted average of six different indicators (see Box 1). While the weights are admittedly somewhat arbitrary, the main advantage of the index is its reliance on publicly available information.

Table 1 presents a detailed account of relative country performance, looking successively at the Top 50, Top 100, Top 200 and Top 500 universities in the Shanghai ranking. To better see how to read this table, consider first the column "Top 50". The best university in the Top 50 is given a score of 50, the next best university is given grade 49, and so on down to a score of 1 for the least performing university within the Top 50. For each country (or region), we then compute the sum of Top 50 Shanghai rankings that belong to this country, and divide the sum by the country's population. Finally, all the country scores are divided by the US score, so that each entry in the

[2] This Policy Brief does not deal with all the various roles and functions of universities, solely their research function. An upcoming Bruegel Blueprint will provide a fuller analysis of how universities perform against a broader set of objectives. Furthermore, this Policy Brief does not discuss the potential of EU-level policy to add value. This will also be dealt with in the upcoming Blueprint.

Box 1 The Shanghai index

This index aggregates six different indicators of research performance:

— The number of alumni from the university winning Nobel Prizes in physics, chemistry, medicine, and economics and Fields Medals in mathematics
— The number of university faculty winning Nobel Prizes in physics, chemistry, medicine, and economics and Fields Medals in mathematics
— The number of articles (co-)authored by a university faculty published in *Nature* and *Science*
— The number of articles (co-)authored by a university faculty published in Science Citation Index-expanded and Social Science Citation Index
— The number of highly cited researchers from the university in 21 broad subject categories
— The academic performance with respect to the size of the university.

Note that the Shanghai index tends to undervalue countries where a great deal of academic scientific research takes place outside universities (the Max Planck institutes in Germany) or in centres whose researchers are affiliated with several universities (the CNRS laboratories in France). This partly explains the poor performance of France and Germany in Table 1.

column "Top 50" can be interpreted as a fraction of the US per capita performance for the Top 50 universities. This gives our Country Performance Index for the Top 50 universities. The same logic applies, respectively, to the "Top 100", "Top 200" and "Top 500" columns, where the best university receives a score of, respectively 100, 200 and 500, and the last one always receives a score of 1. There are, obviously, fewer zero entries in a column as one moves from the Top 50 to the Top 500 as it is easier for a country to have universities among the latter than the former.

Table 1 reveals several interesting findings:

— First, the United States completely dominates all European countries in the Top 50 universities. Only Switzerland and the United Kingdom rival the US on a per capita basis. By contrast, the EU15 and EU25, with a greater population than the US, score much lower.
— Second, the top 4 US states (Massachusetts, California, New York and Pennsylvania) score better than any European state in the Top 50 and Top 100.
— Third, country performance becomes more equalized as one enlarges the number of universities considered. In particular the gap between the EU15 or the EU25 and the US narrows down as one moves from the Top 50 to the Top 500. In part this is due to the way the scores are constructed, but it mostly reflects a reality: American universities dominate European universities in the top tier (the Top 50 and Top 100), but Europe has many good universities in the second (the next 100) and the third (the next 300) tiers.
— Fourth, there are important differences among European countries: Switzerland, the UK and Sweden do particularly well, even in the Top 100, where they out-perform (Switzerland and Sweden) or almost match (the UK) the United States on a per capita basis. The rest of Scandinavia (Denmark and Finland), Belgium and the Netherlands also do pretty well in the Top 200 and Top 500. By contrast, Southern and Eastern Europe lag far behind. France and Germany do relatively poorly, except in the third tier, the universities ranked between 301 and 500.

Table 1 Country performance in the Shanghai ranking
(measured as percentages of the US per capita performance)

Country	*Population (in million)*	*Top 50*	*Top 100*	*Top 200*	*Top 500*
Austria	8.2	0.0	0.0	0.4	52.6
Belgium	10.4	0.0	0.0	61.3	122.4
Czech republic	10.2	0.0	0.0	0.0	13.1
Denmark	5.4	0.0	74.6	113.5	160.5
Finland	5.2	0.0	45.5	75.4	80.5
France	60.2	3.0	15.2	28.6	45.1
Germany	82.5	0.0	17.00	36.5	67.0
Greece	11.1	0.0	0.0	0.0	12.2
Hungary	10.1	0.0	0.0	0.0	13.3
Ireland	4.0	0.0	0.0	0.0	50.0
Italy	57.6	0.0	0.0	11.1	33.9
Netherlands	16.3	20.2	50.7	75.9	131.3
Poland	38.2	0.0	0.0	0.0	3.5
Spain	42.7	0.0	0.0	0.1	14.2
Sweden	9.0	6.7	116.5	178.8	216.9
UK	59.8	72.0	86.1	98.0	123.9
EU15	383.3	12.7	26.0	41.0	67.3
EU25	486.6	10.0	20.5	32.4	53.9
Norway	4.6	0.0	65.8	90.6	107.0
Switzerland	7.4	97.1	165.5	228.1	229.6
Australia	20.1	0.0	31.4	65.8	100.7
Canada	31.9	39.3	54.2	62.9	103.6
Japan	127.7	14.3	17.2	24.3	26.7
USA	293.7	100.0	100.0	100.0	100.00
California	36.1	234.2	198.5	163.2	103.2
Massachusetts	6.4	448.7	307.8	301.7	263.0
New York	19.3	195.7	167.4	138.7	147.7
Pennsylvania	12.4	110.7	176.9	161.0	115.2
Texas	22.9	32.7	60.9	82.8	102.5

3. What explains research performance in Europe?

An obvious starting point for economists is to look at money. Table 2 presents aggregate data on the levels of private and public expenditure on higher education across countries. The main findings are that:

— Richer countries spend relatively more on higher education than poorer countries.

Table 2 Public and private expenditure on higher education in 2001

In thousands of Euros per student				*As a % of GDP*		
Country	*Public*	*Private*	*Total*	*Public*	*Private*	*Total*
Austria	11.0	0.5	11.5	1.4	0.1	1.5
Belgium	10.6	1.6	12.2	1.4	0.2	1.6
Czech R.	2.3	0.4	2.7	0.8	0.1	0.9
Denmark	25.6	0.4	26.0	2.7	0.0	2.7
Finland	10.3	0.3	10.6	2.1	0.1	2.2
France	7.5	1.2	8.7	1.0	0.2	1.2
Germany	11.5	0.9	12.4	1.1	0.1	1.2
Greece	3.3	0.0	3.3	1.2	0.0	1.2
Hungary	2.6	0.6	3.2	1.1	0.3	1.4
Ireland	9.7	1.6	11.3	1.2	0.2	1.4
Italy	5.6	1.4	7.0	0.8	0.2	1.0
Netherlands	13.0	2.7	15.7	1.3	0.3	1.6
Poland	1.7	-*	-*	1.1	-*	-*
Spain	4.0	1.2	5.2	1.0	0.3	1.3
Sweden	18.9	1.8	20.7	2.1	0.2	2.3
UK	8.4	3.1	11.5	0.8	0.3	1.1
EU25	7.3	1.4	8.7	1.1	0.2	1.3
US	16.6	19.9	36.5	1.5	1.8	3.3
Japan	6.5	7.3	13.8	0.5	0.6	1.1

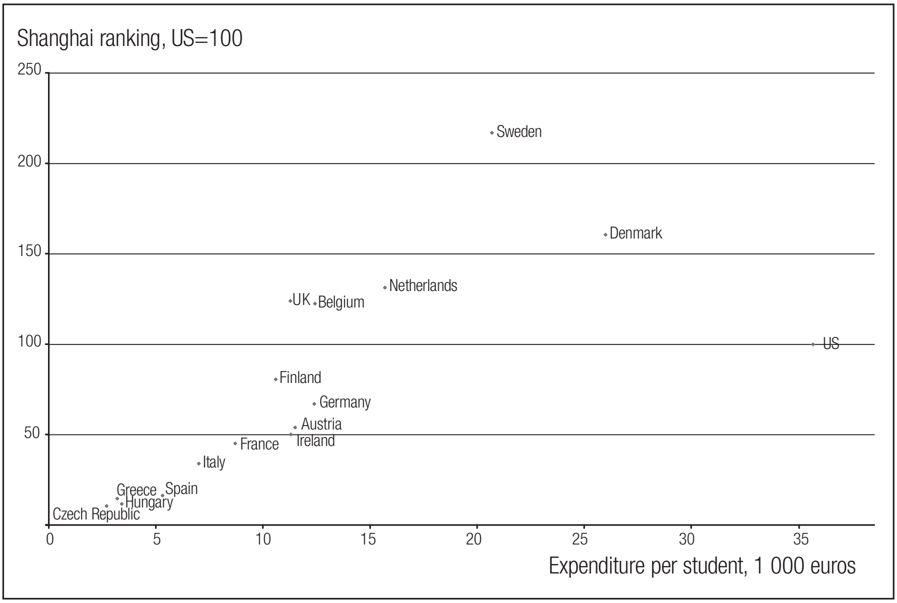
Source: European Commission, DG Research; *: not available. Note: not PPP converted.

— The US spends a lot more on higher education than any European country, especially thanks to private funding. But public spending alone is relatively higher than in the EU.
— Scandinavia also spends a lot, with most of the money coming from public sources.
— The UK spends surprisingly little (more on this later).

Figure 1 shows that there is a strong positive correlation between expenditure per student (from Table 2) and country performance (measured by the Top 500 performance values in Table 1).

However, these aggregate data do not indicate how the money is split between higher education institutions, in particular between research-oriented and teaching-oriented universities. In the remainder of this section we therefore present the results of a survey questionnaire which elicits information on individual budgets and on the governance of top research performers.

Figure 1 Relationship between expenditure per student and country performance



Source: Country performance index: Table 1; Expenditure per student: Table 2.

A. *A survey of European universities*

A survey questionnaire was sent to the European universities in the 2006 Top 500 Shanghai ranking[3]. We received 71 responses, an overall response rate of 36 %, which can be considered very satisfactory. We decided to focus on the ten countries for which the response rate was at least 25 % and the number of respondents at least two[4]. This left us with a total sample of 66 universities, with an average response rate of 41 % for the ten countries considered. We were able to check that, for each country, respondent universities have an average Shanghai 500 rank pretty close to that of the whole population of universities from that country, so that we could be satisfied of the representativity of our sample[5].

[3] The 2006 Shanghai ranking includes roughly 200 European universities belonging to the EU25 and Switzerland.

[4] The ten countries are: Belgium (4 responses out of 7 universities in the Shanghai 500 ranking), Denmark (2 out of 5), Germany (11 out of 40), Ireland (2 out of 3), Italy (9 out of 23), Netherlands (4 out of 12), Spain (6 out of 9), Sweden (5 out of 11), Switzerland (6 out of 8) and the UK (17 out of 43). We left out France, because only 4 out of 21 universities responded and moreover, university budgetary data are not comparable with those of other countries.

[5] In fact, respondents had a somewhat higher rank for all countries except for Spain.

Table 3 Characteristics of the universities in the sample (averages)

	Age (in years)	*Number of students (in thousands)*	*Budget per student (in thousand Euros)**	*Public status (1 if public, 0 if private)*	*Budget autonomy (1 if yes, 0 if no)*	*Building ownership (1 if yes, 0 if no)*	*Hiring autonomy (1 if yes, 0 if no)*	*Wage-setting autonomy (1 if yes, 0 if no)*	*% of Faculty with in-house PhD degree*
Belgium	284	21.7	11.3	0.5	0.4	1.0	1.0	0.0	63
Denmark	59	18.2	11.4	1.0	1.0	0.3	0.5	0.5	40
Germany	289	26.2	9.6	0.9	0.0	0.5	0.8	0.0	8
Ireland	259	16.3	12.7	0.5	0.5	1.0	1.0	0.0	49
Italy	444	44.9	10.1	1.0	0.9	1.0	0.4	0.0	24
Netherlands	217	21.4	20.5	0.8	0.8	1.0	0.8	0.2	33
Spain	342	44.8	7.0	1.0	0.5	1.0	0.5	0.0	69
Sweden	266	27.1	16.2	0.8	0.8	0.2	1.0	1.0	58
Switzerland	326	12.8	26.2	0.8	0.1	0.4	0.8	0.0	24
UK	242	14.6	24.5	0.5	0.9	0.9	1.0	0.8	8
Total	290	24.9	16.1	0.75	0.55	0.76	0.8	0.31	29

*: PPP adjusted.

Table 3 provides country averages on a variety of dimensions[6]. It confirms the high degree of heterogeneity between countries for the universities in the Top 500:

— Southern European (Italy and Spain) countries have very large (more than 40 thousand students on average) but not well-funded universities.
— Sweden and the Netherlands have universities of average size (20-25 thousand students), and better funded.
— The UK and Switzerland have small (10-15 thousand students) and very well funded universities. Comparing with the aggregate information on expenditure in Figure 1, one observes that the UK significantly favours top research performers since the universities in our sample (which belong to the group of top universities) have a budget per student about twice as large as the average for all universities in the country.

There is also a great deal of heterogeneity – albeit with some general trends – as far as university governance is concerned:

— State intervention is clearly pervasive, even when universities are not public.
— Wage-setting autonomy is rare, with Sweden and the UK being the foremost exceptions.
— Building ownership by the university is commonplace (except in Scandinavia and Switzerland).
— Hiring autonomy is prevalent, except in Southern Europe.

[6] We obtain very similar results when looking at medians rather than averages.

— Endogamy (measured as the percentage of faculty trained in-house at the PhD level) seems to be negatively correlated with country size: it is high in small countries (Belgium, Denmark, Ireland and Sweden, but not in Switzerland which is highly open to hiring scholars with PhDs from other institutions), and small in large countries (Germany, Italy and the UK, but not in Spain). This finding clearly reflects the absence of significant academic mobility between European countries.

A striking fact is thus the high variance in university governance across European countries, even among those which are performing well in terms of research. For example, among the three European countries with the best performance index, endogamy is high in Sweden but low in Switzerland and the UK, and universities are mostly public in Denmark, Sweden and Switzerland whereas they are mostly private in the Netherlands and the UK.

One dimension where there is little variance across European countries is the age of universities. Top European universities are old institutions: the average age of the 66 universities in our sample is nearly 300 years. It ranges from 220 years in the Netherlands to 450 years in Italy. The only outlier is Denmark where the average age is only 60 years. This suggests that European universities have a lot of accumulated knowledge, but may also be complicated to reform.

B. Preliminary evidence

Our survey allows us to examine how budget per student and various measures of university governance correlate with research performance measured by the Shanghai ranking. Table 4 shows that the research performance of a university is:

— positively correlated with the size of its budget per student: the higher the budget per student the better the performance;
— negatively correlated with its degree of public ownership: private universities perform better than public institutions;
— positively correlated with its budget autonomy: not being required to have its budget approved by governmental authorities is associated with better performance;
— not correlated with its building ownership: more autonomy with respect to buildings is not associated with better performance;
— positively correlated with its hiring and wage-setting autonomy: universities that decide on faculty hiring and set faculty wages do better;
— negatively correlated with its degree of endogamy in faculty hiring: universities which tend to hire their own graduates as faculty do less well.

Taken together these results suggest that the research performance of a university is positively affected by all our measures of university autonomy (except for building ownership), and also by funding. However, they not tell us: (i) which of these autonomy indicators dominates and how interrelated they are; (ii) whether funding and autonomy improve performance separately from one another, or whether there are positive interactions between the two. We now try to answer these questions with appropriate statistical instruments.

C. *Funding and autonomy*

We use regression analysis, a statistical technique for the investigation of relationships between variables, to assess the effect of budget and governance on research performance measured by Shanghai rankings.

We are interested in the effect of budget and university governance on university research performance. However we need to begin by taking into account two other factors that also affect Shanghai rankings, our measure of university research performance. The first is the size of the university. As Box 1 clearly indicates, other things equal, larger institutions are likely to have a better Shanghai ranking because they have more researchers. We do not have data on the number of researchers in our survey so we proxy the size of the university by the number of students. The second factor is the age of the university. Box 1 also indicates that, other things equal, older institutions may have a better Shanghai ranking because they have more alumni.

As expected, the regression analysis indicates that the research performance of universities is positively associated with their size and their age. More importantly, it also confirms the existence of a positive linkage between budget per student and research performance. These effects are statistically significant.

Once these three important factors (size, age and money) are taken into account, it turns out that one of the six governance indicators reported in Table 4, namely budget autonomy, has a statistically significant effect on research performance. The others have no statistical impact on performance.

Table 4 Correlation between budget and university governance, and research performance*

Characteristics	*Correlation coefficient*
Budget per student	+ 0.61
University governance:	
Public status (1 = public; 0 = no)	– 0.35
Budget autonomy (1 = yes; 0 = no)	+ 0.16
Building autonomy (1 = yes; 0 = no)	– 0.01
Hiring autonomy (1 = yes; 0 = no)	+ 0.20
Wage-setting autonomy (1 = yes; 0 = no)	+ 0.27
Percent of faculty with internal PhD degree	– 0.08

* Measured by the (logarithm of the) Shanghai ranking.

Table 5 Effect of budget and autonomy on research performance*

Variable	*Effect on research performance*
Size of the university (number of students)	+
Age of the university	+
Budget per student	+
Budget autonomy	+
Interaction between budget and autonomy	+

* Measured by the (logarithm of the) Shanghai ranking.

But our main result is not simply that more money or more autonomy is good for research performance. It is that more money has much more impact when it is combined with budget autonomy. To be more precise: we find that having budget autonomy doubles the effect of additional money on university research performance.

Hence, increasing budget per student helps research performance, and having budget autonomy doubles this beneficial effect.

This message based on the research performance of European universities is reinforced by the analysis of American universities presented in the next section.

4. Lessons from US evidence

The United States provide a wealth of information that can be used to go one step further in the analysis of research performance. Specifically, for the US we have access to a rich data set across US states and across time on education spending and patenting. For each state, we have at our disposal yearly information on university funding and governance and on patenting. We are able, therefore, to examine the effect of university funding and governance directly on innovation activity, rather than solely on university research performance.

Box 2 University funding, autonomy and innovation: Data and methodology

Data

For research expenditure, we use the detailed data in Aghion *et al.* (2007)[1] on how much each state spent on each type of education in all years from 1947 to 2004. We know in particular from these time series how much each US state spent on a given cohort of individuals (e.g. born in year X) in each year. Thus we know how much was spent on average on each individual at every stage of his or her studies (from primary school to post-graduate college).

For governance, we consider two alternative measures of university autonomy at the state level: (i) the percentage of universities that are private, keeping in mind that private universities are, on average, more autonomous than public universities; (ii) an aggregate autonomy index for public universities, which is constructed on the basis of several component factors. This index takes the maximum value when the public universities in the state: (a) set their own faculty salaries; (b) set their own tuition fees; (c) have lump sum budgeting (as opposed to line item budgeting); (d) can shift funds among major expenditure categories; (e) retain and control tuition revenue and/or grants; (f) have no ceiling on external faculty positions (and therefore need not hire faculty internally); (g) have no ceiling on external non-faculty positions (administrators or technicians); (h) have freedom from pre-audits of their expenditure; (i) can carry over year-end balances (rather than returning them to the state). It turns out that, like in the case of European universities, the most statistically important component factor of this aggregate index is budget autonomy.

Statistical test

We examine the effect on patenting in a US state, of increasing research education funding by $1,000 per year and per person over a sustained period, respectively in states with highly autonomous universities and in states with less autonomous universities.

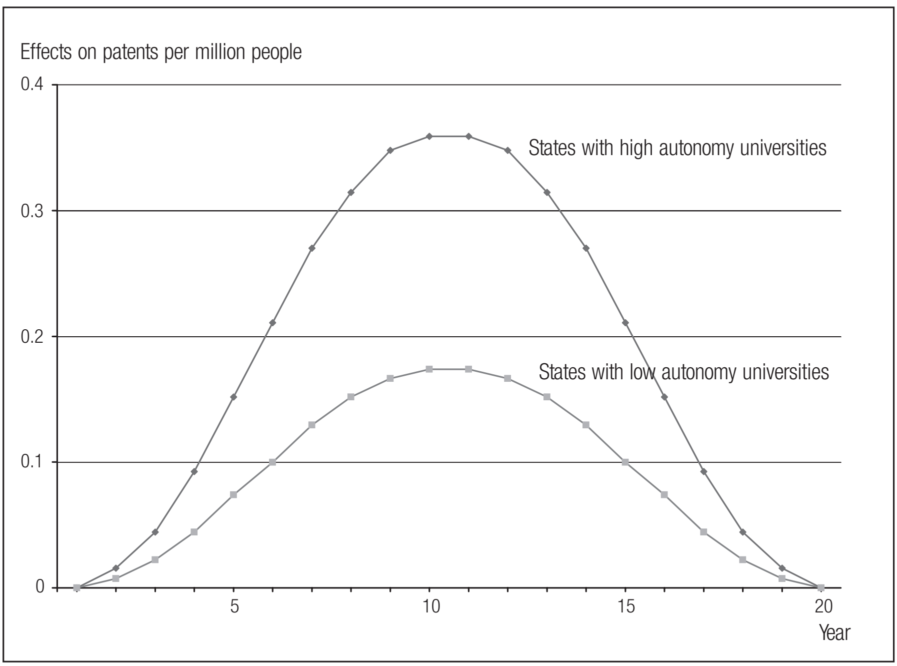
Figure 2 illustrates a key result from our test: States with highly autonomous universities enjoy an accumulated impact of the research education funding on innovation which is roughly twice as high as that enjoyed by states with less autonomous universities.

[1] P. Aghion, L. Boustan, C. Hoxby and J. Vandenbussche (2007), "Exploiting States' Mistakes to Evaluate the Impact of Higher Education on Growth", mimeo, Harvard.

Interestingly, there is considerable variation in university governance across states. States vary not only in the relative importance of private versus public universities, but also in the degree of autonomy granted by state authorities to public universities. Sometimes, even neighbouring states display sharp differences in governance. For instance, public universities in Illinois enjoy rather low autonomy on average, while their neighbours in Ohio enjoy instead high autonomy. These differences are persistent over time and often go back to the idiosyncratic origin of American universities, which in turn reflect differences in the preferences of university founders (e.g. Benjamin Franklin founded the private University of Pennsylvania, whereas Thomas Jefferson was the founder of the public University of Virginia).

Our strategy is to take US states' differences in university autonomy as given and then ask the following question: Does a given investment in higher education produce more patenting in a US state if universities in that state are more autonomous? The details of the statistical test are reported in Box 2. The answer to our question is a resounding yes: As illustrated in Figure 2, the effect of additional spending on patenting is roughly twice as high for states with more university autonomy. Autonomy therefore greatly enhances the efficiency of spending. This result confirms and nicely complements the one from Section 3.

Figure 2 Effects on patents of an increase in higher education expenditure, states with high autonomy vs. low autonomy universities



Source: Authors' own computations.
Note: The increase in expenditure is assumed to last from year 1 to 6. The effect on patenting accordingly starts in year 2, peaks in years 10 and 11, and ends in year 20.

5. Conclusions

In this brief we have investigated the relationship between university governance and funding on the one hand and various measures of performance on the other hand. In the first section we have tried to link our Country Performance Index based on the Shanghai ranking of universities to different aspects of university governance drawn from a survey questionnaire. In the second section of the brief we have assessed how university autonomy affects the patenting impact of university research funding.

Several interesting findings come out of our investigation.

First, the performance gap between Europe and America is large, in particular for the best-performing universities.

Second, as we broaden the investigation from the Top 50 to the Top 500 universities in the Shanghai ranking, the relative performance of European countries improves compared to the US. This, in turn, suggests strongly that quality variance is lower among European universities than among their American counterparts. It also suggests that what Europe lacks most is top-class universities.

Third, there is more than one model of university system that appears to work. For example, both Switzerland and Sweden are doing well with most universities being public, while the UK also performs well with a higher share of private universities, but also higher tuition fees and a higher degree of student selection. The UK, however, differs significantly from Switzerland and Sweden in one respect. All three perform very well in the top tier (Top 50 and Top 100), but the UK performs relatively less well in the remaining of the Top 500. This is due to the fact that the UK heavily concentrates its less than average higher education budget (in terms of GDP) on top institutions.

Indeed, a fourth lesson is that money helps performance.

Fifth, autonomy is good for research performance.

Sixth, autonomy and funding are complementary inputs to performance: more autonomy increases the extent to which additional research funding improves performance measures at the university and at the national/state/regional levels.

Policy lessons

What should be done to improve the performance of European universities?

1. European countries should invest more in their university systems. On average EU25 members spend 1.3 % of their GDP on higher education, against 3.3 % in the US. European countries should increase funding for higher education by at least 1 percentage point over the next ten years. It remains an open question how the burden of this increase is to be shared between public budgets and private funding, including tuition fees.
2. For this effort to pay off, European universities should become more autonomous, in particular with regard to budgets, and also in hiring, remuneration, programme and student selection, particularly at Master's level. What matters for good performance is both money and good governance. The two are complementary: increasing university budget has more impact with good governance and improving governance has more impact with higher budgets. We are aware,

however, that greater autonomy can be perverse and that it must be accompanied by greater performance evaluation.

Of course this Brief has focused mainly on the research function of universities and has left aside politically-sensitive issues of tuition fees and student selection, which are perhaps more directly related to the teaching function, although they also impact on research. Yet, we are confident that a reform stressing increased budget per student and greater autonomy (together with greater evaluation) will be performance enhancing, either alone or as part of a more radical overhaul of the university system, involving tuition fees and student selection. So far, our partial evidence, which will be further examined in our Blueprint, leads us to believe that there is more than one university system that works and, therefore that there are diverse paths to university reform.

Research and higher education in a federal system: The need for a European University Charter

Françoise Thys-Clément [1]

Summary

The need to increase the level of resources channeled to fundamental research and higher education is broadly acknowledged. These two activities have all of the characteristics of collective or public goods: they thus need to be primarily funded with public money. Traditional economic theory suggests that the responsibility for financing research should be given to the authority with the widest jurisdiction: the one that best corresponds to the natural dissemination area of research outcomes. More recent developments of the economic theory can also help identify ways of improving the governance of universities. Finally, securing a better financing for the highest segments of higher education requires the adoption of a European University Charter. The latter would guarantee adequate and stable funding in the medium term, and allow the sector to achieve its missions. This charter should also help universities clarify their governance methods.

1. Introduction

This article summarises the arguments developed in Thys-Clément (2006) for higher education and basic research reorganization through analyses of the recommendations concerning budgetary federalism theory in the EU and Belgium. This public competences devolution depends on the institutional architecture of the concerned geographic areas.

The Sapir Report (2004) recalls the European financing deficit for higher education and research-development, in comparison with the United States. The Report focuses its recommendations on a major European budget reorganization, in particular a major financial effort to be carried out on investment in human capital in higher education as well as research. This paper does not deal with the private financing of these activities, but focuses on their collective goods aspects. The first part is

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devoted to basic research and its externalities and heterogeneous or homogeneous preferences expressed by researchers and citizens. We sum up the Eurobarometer results (2005) and the recommendations of the "High Level Group 3 % Belgium". Basic research is the main concern of universities, which is why the second part of this paper analyses their missions within the European context. In our conclusion, we posit for the setting up of a European University Charter in order to assure to universities a funding which may enable to increase higher education.

2. Organization of the funding of basic research

From society's viewpoint (Stiglitz and Walsh, 2002), basic research is a particularly interesting case. Basic research is the kind of fundamental inquiry that produces a wide range of applications. Therefore, the externalities flowing from basic research are extreme implying that it can be considered to be a pure collective good. This kind of good, also called public good, is defined by two main properties. First, it is difficult to exclude anyone from its benefits, because basic research involves the discovery of underlying scientific principles or facts of a nature which cannot be patented. Second, the marginal cost of an additional individual enjoying a public good is zero.

These properties allow knowledge to increase and spread almost without limit. Indeed, sharing the fruits of basic research as soon as they become available can yield enormous benefits – as all researchers can use this knowledge in their quest for innovation. It is well-known that the market will not be able to supply such a public good because enterprises will not exclusively own the benefits.

The fact that economists are concerned about the insufficient funding for basic research spending is not new. Kindlerberger (1986) showed that there is a strong tendency for public goods to be underproduced even within a nation bound by a social contract implying the constraint of collecting taxes. From there, the problem of funding international public goods is quite serious since there is no international government. This analysis raises the question of researchers' mobility and of the brain-drain as well as the leadership role of America with the United States accusing the rest of the world of being free-riders, that is to say "stowaways" taking advantage of their research programme.

The funding of basic research in a public structure with different levels can be tackled through the literature on fiscal federalism. The traditional literature (Tiebout, 1956; Oates, 1972; Musgrave, 1959) is currently being re-examined under the name of "Second Generation Theory of Fiscal Federalism" (Oates, 1999, 2004; Wildasin, 2004). Oates (1999) does not cover the political science usage referring to a political system with a constitution that guarantees some range of autonomy and power to different levels of government. For economists, nearly all public sectors are more or less federal in the sense that different levels of government provide public services and have some scope for de facto decision-making authority irrespective of the formal organization of a federal constitution.

The traditional literature contends that the central government should have the responsibility for macroeconomic growth, for income redistribution and must provide certain public goods (collectives) that provide services to the entire population.

This literature characterizes the nature (private or public) of basic research and it also indicates at which geographical level public decision-making should take place.

The modern theory of fiscal federalism opens new research questions in the area of contemporary analyses of public choice related to the theories of industrial organization, principal-agent, the economics of information as well as contract theory.

This section calls on traditional concepts to determine the level of the political territory in charge of the funding of basic research, the new theoretical precepts lead to the European University Charter perspective in Section 3.

Using the results of Eurobarometer (2001), Alesina and Spolaore (2003) consider that European institutions should centralize prerogatives linked to economies of scale and considerable externalities and for which the preferences of European citizens are homogeneous. They consider that the areas of education and research show very high levels of heterogeneity of European preferences and limited economies of scale. Therefore, Alesina and Spolaore advocate the shared devolution of those public competences, linked to education and research, at the EU member state level and consider that it is not clear why the Union should enjoy any presence at all.

This point of view is far from being unanimously accepted. Von Hagen and Pisani-Ferry (2003) ponder the question of "why Europe does not resemble what economists would like?". They also define the theoretical framework of fiscal federalism to study the sharing of public competences inside the EU. Their point of view is summed up in Table 1 below.

Table 1 Theoretical and effective allocations of responsibilities in the EU15

Domain	*Externalities and economy of scale*	*Heterogeneity of preferences*	*Allocation*	
			Theoretical	*Effective*
Research	Strong	Weak	EU	Member states principally

The question of the heterogeneity of European preferences is not identical for the organization of research and that of higher education. For the latter, the Bologna process aims at improved and increased mobility of students, with the purpose to decrease heterogeneity of programme and teaching subjects. This is supported by most EU-member states.

As for the heterogeneity of European preferences in the field of research practice, it would appear to have decreased considerably due to the success of the European policy in favor of researchers' mobility. For example, it is known that the Marie Curie grant programme is substantially oversubscribed and is not able to keep up with researchers' and universities' or research institutions' demands.

The latest Eurobarometer (2005a) on Science and Technology provides interesting trends on the mentality of European citizens. A significant majority believes that "even if it brings no immediate benefits, scientific research which adds to knowledge should be supported by Government". Also, the survey's results posit for an increased cooperation among European researchers, a reinforced coordination between member states and the EU. Finally, a large consensus is reached on the fact that “Europe should aim to lead the World in science and technology”.

Capron *et al.* (2000) showed that, as the new Belgian institutional system is still in a transitional phase, it is difficult to predict in which direction it will evolve. It is quite difficult to analyze the organization of scientific and technological policies inside the Belgian system, given the great autonomy of regions and communities. They represent the main competent authorities in this area.

The question that is asked is: “Does Belgium still need a federal science and R & D policy?”.

The argument according to which it is more and more difficult to distinguish the phases of basic research from those of applied research tell us that the answer should be positive, since scientific truths go beyond regional and linguistic borders. This is also the answer of the High Level Group (HLG) 3 % Belgium which has expressed its recommendations about the missing links in scientific policy and Belgium R & D set up (2005). The work of the HLG 3 % has crystallized into six major areas of urgent policy action to:

- answer a major public funding injection in the national public research infrastructure;
- radically improve the financial conditions of private R & D investments;
- ensure that high-tech sectors become sources of diffusion;
- reinforce Belgian attractiveness for knowledge workers;
- create a Belgian Research Area inspired by the European Research Area within the EU;
- adapt the legal and regulatory framework of innovation.

3. Why is it necessary to draw up a European University Charter?

Higher education funding, and specifically that of universities must be increased within the EU. To resort to the private sector might be justified but, as for the teaching mission, it is difficult to set it up politically in several countries. The analysis of the previous paragraph suggests that a demand of financial aid must be introduced to the EU. The third part suggests the setting-up a European University Charter which would organize a stable and long-term funding of university activities along with shared principles of governance.

It is well-known (OCDE, 1999) that in most countries research is mainly conducted within universities. Although this is not the case in France, Aghion and Cohen (2004) underline that the knowledge-based economy will impose it. This is due to the fact that high level research on the knowledge borderline needs multiple interactions between basic and applied research. This complementarity imposes a link with doctoral training within university organizations. The arguments relative to funding and environmental changes may be summed up by the recommendations of the most recent panel in charge of the five-year assessment of the European Union Research Framework programmes (European Commission, 2005b) according to which “Universities and research institutions have been able up to now to develop and maintain a European knowledge base. In many areas, this capacity still exists. However, only a few European universities are recognized as leaders at the global level. This is partly due to a resource deficit combined with the fragmentation of the RTD European landscape.

The balance of power with the university environment has been modified. Universities are solicited from all fronts. An important literature exists on several aspects of the operating of research. The different viewpoints and empirical results obtained in the few recent studies in Europe are analyzed in Thys-Clément (2002). Cabiaux and Thys-Clément (2004) illustrate the particular case of the Université Libre de Bruxelles.

Many official European speeches exhort universities to increase their effectiveness through cooperation mechanisms and effort complementarities. But it is well-known that, these institutions experiment severe competition to obtain the public funds needed not only for their supporting role of the economic development, but which are essential to maintain the quality of their core missions: knowledge creation, basic research and higher education.

An abundant literature exists as well on the changes which have occurred in university governance; Thys-Clément (2001) approaches this question.

To understand the changes which have occurred within universities, Mas-Collel (2003) underlines that, concerning the governance, the trade-off between institution autonomy and political control is delicate. But while highlighting the necessity of a "careful theoretical attention", Mas-Collel (2003) considers that the issue of information asymmetry, typical of the principal-agent problem, may be overcome.

He also mentions that the procedures of choice or selection of the teaching-researchers are vital. One precept is that given the asymmetries of information, the difficulties in establishing "talents", institutions should concentrate on the quality of research when recruiting its personnel, whilst implementing institutional mechanisms to guarantee that they supply high quality education.

Dewatripont *et al.* (2001) use the theory of incentives to take into account the recognition of the work of the researchers-teaching staff. It is hence necessary to take into account incentives, not only internal (salaries, promotions) but also external, via scientific reputation. In an environment in which synergies between research and education would advise against individuals being too specialized, it is nevertheless necessary to ensure to supply incentives to fulfill these two tasks in a balanced manner.

Mas-Collel suggests that the EU should exploit the cultural diversity of its universities to create a knowledge market. But he adds that the university's social interest, i.e. to educate future generations and develop knowledge, has the characteristics of a collective good, of a public good.

4. Conclusion

The necessity to increase the financial resources for research and higher education is widely recognized. These two activities present all of the features of collective goods, of public goods that lead the public sector to become the principal funder.

The traditional literature on budgetary federalism allocates the funding of high-externality activities to the political authority with the widest geographical spread.

The recent development of this theory may help to solve the problem of governance of universities.

A more effective funding of the "*supérieur du supérieur*" can be organized through a European University Charter which guarantees a stable funding, in the medium term, to complete universities' core missions. This Charter should also allow universities to clarify their governance methods.

References

AGHION P. et E. COHEN (2004), "Education et croissance – Conseil d'Analyse économique", *La Documentation Française*, 1er trimestre.

ALESINA A. and E. SPOLAORE (2003), *The size of nations*, MIT.

CABIAUX V. and F. THYS-CLÉMENT (2004), "The New Working Conditions of Researchers: the Case of Université Libre de Bruxelles" In: *University Research Management*, OECD Publishing.

CAPRON H., M. CINCERA and M. DUMONT (2000), "The Institutional Profile in the National Innovation System of Belgium" In: H. Capron and W. Meeusen (Eds.), *Physica-Verlag, Springer-Verlag Co.*

DEWATRIPONT M., I. JEWITT and J. TIROLE (2001), "Multitask Agency Problems: Focus and Task Clustering", In: M. Dewatripont, F. Thys-Clément and L. Wilkin (Eds.), *The Strategic Analysis of Universities: Microeconomics and Management Perspectives*, Editions de l'Université de Bruxelles, Brussels.

EUROPEAN COMMISSION (2005a), *Europeans, Science and Technology*, Special Eurobarometer, 224/Wave 63.1.

EUROPEAN COMMUNITIES (2005b), *Five-year assessment of the European Union research framework programmes 1999-2003*, Ormala, E. (Chairman of the panel), Vonortas, N. (Rapporteur of the panel), Ayme S., Cok L., Donnelly D., King J., Mandl C., Meyer-Krahmer F., Oleksy E.H., Quintanilha A., Stame N., Tarrach R. and Thys-Clément F.

KINDLERBERGER C.P. (1986), "International Public Goods without International Government", *The American Economic Review*, 76(1), pp. 1-13.

MAS-COLLEL A. (2003), "The European Space of Higher Education: Incentives and Governances Issues", *Rivista di Politica Economica,* Nov.-Dec., pp. 9-27.

MUSGRAVE R.M. (1959), *The Theory of Public Finance,* McGraw-Hill, New York.

OATES W.E. (1972), *Fiscal Federalism*, Harcourt Brace Jovanovich, New York.

OATES W.E. (1999), "An essay on fiscal federalism", *Journal of Economic Literature*.

OATES W.E. (2004), "Toward a second-generation theory of fiscal federalism", unpublished paper.

POLITIQUE SCIENTIFIQUE FÉDÉRALE (2005), *Recherche, technologie et innovation en Belgique: les chaînons manquants*, Haut Conseil 3 % de la Belgique, R&D et innovation en Belgique, Série d'études, 07.

SAPIR A., P. AGHION, G. BERTOLA, M. HELLWIG, J. PISANI-FERRY, D. ROSATI, J. VIÑOLS and H. WALLACE (2004), *An Agenda for a Growing Europe*, The Sapir Report, Oxford University Press.

STIGLITZ J.E. and C.E. WALSH (2002), *Economics*, 3rd edition, W. W. Norton and Co, New York.

TIEBOUT C.M. (1956), "A Pure Theory of Local Expenditures", *Journal of Political Economy*, 64, pp. 416-424.

THYS-CLÉMENT F. (2001), "University Governance: External Pressures and Internal Evolutions" In: M. Dewatripont, F. Thys-Clément and L. Wilkin (Eds.), *The Strategic Analysis of Universities: Microeconomics and Management Perspectives*, Editions de l'Université de Bruxelles, Brussels.

THYS-CLÉMENT F. (2002), "Changes in Research Management: the New Working Conditions of Researchers" In: *The Belgium Innovation System: Lessons and Challenges,* Vol. II, Federal Office for Scientific, Technical and Cultural Affairs.

THYS-CLÉMENT F. (2006), "The assignment of responsibilities for science and R&D expenditures to different levels of government in federal system. The need for an European University Charter", *Les Cahiers du CRHIDI*, 25, Centre de recherches en histoire du Droit et des Institutions – Facultés universitaires Saint-Louis.

VON HAGEN J. and J. PISANI-FERRY (2003), "Pourquoi l'Europe ne ressemble-t-elle pas à ce que voudraient les économistes?", *Revue Economique*, 54(3).

WILDASIN D.E. (2004), "The Institutions of Federalism: toward an analytical framework", *National Tax Journal*, 57, pp. 247-72.

Financing Bologna: which country will pay for foreign students?

Marcel GÉRARD [1]

Summary

In an integrated set of jurisdictions, where residents of one country may obtain higher education in another country and later return home (with some probability), the question arises of which country has to pay for higher education abroad, the country of origin of the student, which is likely to benefit from the education acquired abroad, or the country which has produced the extra human capital? This paper, nested in the philosophy of the Bologna process and the reality of today European Union – where such issue is hot for countries like Belgium and Austria, which host numerous students from France and Germany – investigates under which conditions it can be recommended to set up a network of bilateral treaties or a multilateral arrangement, in some sense similar to what exists for taxation, social security or health expenditures, which imposes the country of origin to be responsible for the payment of studies of its resident students either at home or abroad, provided it is in a certified institution.

1. Introduction

The Bologna process is now well known at least among Europeans. It was launched in that Italian city on June 19, 1999 when the representatives of the Ministers of Higher Education of Thirty-one European countries or subnational jurisdictions signed a common declaration, which intended to achieve the following objectives within the first decade of the new millennium:

— Adoption of a system of easily readable and comparable degrees, also through the implementation of the Diploma Supplement, in order to promote European citizens employability and the international competitiveness of the European higher education system.

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— Adoption of a system essentially based on two main cycles, undergraduate and graduate. Access to the second cycle shall require successful completion of first-cycle studies, lasting a minimum of three years. The degree awarded after the first cycle shall also be relevant to the European labour market as an appropriate level of qualification. The second cycle should lead to the master and/or doctorate degree as in many European countries.
— Establishment of a system of credits – such as in the ECTS system [2] – as a proper means of promoting the most widespread student mobility. Credits could also be acquired in non-higher education contexts, including lifelong learning, provided they are recognized by receiving Universities concerned.
— Promotion of mobility by overcoming obstacles to the effective exercise of free movement with particular attention to: (i) for students, access to study and training opportunities and to related services; (ii) for teachers, researchers and administrative staff, recognition and valorization of periods spent in a European context researching, teaching and training, without prejudicing their statutory rights.
— Promotion of European cooperation in quality assurance with a view to developing comparable criteria and methodologies.
— Promotion of the necessary European dimensions in higher education, particularly with regards to curricular development, interinstitutional cooperation, mobility schemes and integrated programmes of study, training and research.

Beyond that however, the various jurisdictions used Bologna to pass a series of reforms not directly related to the original process [3]. Although the Bologna process concerns a geographic area larger than the territory of the European Union, one can say that, together with the Sapir Report and the Lisbon Agenda, it generates a large debate around higher education in Europe – see Bache (2006), Sapir *et al.* (2003), van der Ploeg and Veugelers (2008).

In this paper, we focus on students who are mobile across borders. As long as European students are concerned, two different situations need to be distinguished. On the one hand, students go abroad to get some of the credits, called ECTS, for European Credit Transfer System, needed to obtain a degree – e.g. a master degree can need 120 credits; out of them 30 or 60 may be obtained outside the country of the university that gives the degree; let us add that a full time year of studies usually corresponds to 60 credits; those students are known as Erasmus or Socrates students after the names of the EU program which stimulates those exchanges of students. On the other hand some students already go abroad to get a degree; that category of students is expected to increase in the future since the Bologna process should encourage students to get a first degree at home and a more advanced one abroad;

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[2] ECTS is an acronym for European Credit Transfer System; those credits measure time spent by students and 60 credits are more or less equivalent to a one-year-full-time study.

[3] As an example, let us mention the attempts made in French-speaking Belgium to change the university landscape by gathering the various university institutions into three so called academies, set up around the three main universities of that jurisdiction. For another example, the case of France, see Ahues (2005).

by extension, some students will interrupt their studies at home, go abroad for a semester or a full year and enroll there in a local university in order to get a number of credits that they will further validate on a cursus in their original institution, where they will enroll again when returning home; let us call those students, the Bologna students [4].

In the former case, the school or university of the country of residence of the students – the origin country – receives the whole subsidy or fee and the host institution in no case receives money, the system being based on reciprocity. In the latter case, the country that hosts the students – the higher education production country – supports the cost of their education, except if it is permitted to charge them a fee.

In most EU countries the fee charged to students, if any, is rather symbolic and in no case covers the true cost of studies. Moreover charging a different fee to student resident in the country and to students non-resident in the country violates the non-discrimination principle at the root of the EU process (del Rey, 2001) [5]. This is a key difference between the EU and the US where a State University usually charges a different fee to residents and non-residents of the State. UK departs from the standard EU system by charging larger fees to students; accordingly UK universities are rationally more interested by attracting non EU exchange students.

Thereafter, we disregard the case of Erasmus or Socrates exchange students as well as the case of students from the South coming to study in schools of the North. Rather, we focus on Bologna students. Indeed, by increasing the transparency of diplomas and organizing portable credits, the Bologna process is in itself an incentive for students either to acquire credits abroad, which they can further use to fulfill degree requirements at home, or to get a foreign degree.

Although it greatly facilitates studying abroad, the Bologna process remains silent about the way those studies will be financed. In particular nothing has been decided as to which country will be responsible for organizing the financing of the studies abroad: the country of origin of the student, or the country where the studies take place. In the former case, in the sequel of the paper, we say that the Origin Principle applies, in the latter case, we say that the Production Principle applies. Especially, this paper aims to show under which conditions it can be recommended to set up a network of bilateral treaties or a multilateral arrangement, in some sense similar to what exists for taxation, social security or health expenditures, which imposes the country of origin to be responsible for the payment of the studies abroad of its resident students (Gérard 2006a,b, 2008).

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[4] An example of what may be produced by the Bologna process in the future, and which rises as an issue motivating this paper, is provided by the following observation: during the academic year 2005-2006, in some classrooms of Higher Education Schools of the French speaking part of Belgium a large majority of students were coming from France; most were students who failed entrance competition in their own country. They were expected returning home after completion of their degree and some even return home during their period of studies for field training; they were therefore not expected to contribute to Belgian GDP in the future so that they were actually a cost for Belgium, and represented a typical free riding opportunity for France. Similar features may be observed between Germany and Austria, or between Luxemburg and neighboring countries.

[5] For a justification see http://ec.europa.eu/youreurope/nav/en/citizens/education-study/eulegislation/index.html

Notice that, when we write that a country is "responsible for", we do not mean that this country needs to pay using public funds. It may require that the students contribute partly or totally, or organize a system of contingent loans; that issue is beyond the scope of this paper. For the ease of the exposition, in the sequel of the paper, we do "as if" the payment comes from the authorities of the country, using public funds.

Thereafter we first consider the current system where the cost of studies is supported by the country of production of higher education, and we call that the Production Principle. We show that under that system the number of students studying abroad – actually the number of credits got abroad – is too small, compared to a number decided in a centralized way. Then we turn to the alternative principle, called the Origin Principle, where the cost of the studies is supported by the country of which the students are residents before temporarily migrating for studying purposes. Under that system, the number of credits obtained abroad is still inefficiently low, but less inefficiently low than under the Production Principle. We then conclude that a reform substituting the latter principle for the former is a Pareto improvement. Translated into a feasible design, the exercise is favorable to a system of portable vouchers that the student may use either at home or abroad in higher education institutions recognized by their country of origin. At the moment we write this paper, we know that such a system of cross border portable vouchers exists, directly or indirectly, at least in Switzerland (for studies across the borders of the Canton) and in The Netherlands (for studies across the borders of the country).

Notice that this reform considered in this paper concerns exclusively students of developed countries belonging to the Bologna area.

The organization of the sequel of the paper is the following. In Section 2 we propose a short survey of literature emphasizing the contribution by Mechtenberg and Strausz (2006) which inspired part of the formal analysis that we conduct below. Then in Section 3 we conduct our analysis under the currently applying Production Principle, showing in particular the free riding issue appearing in that context. In Section 4 we compare the outcome under the Production Principle with the Centralized Efficient equilibrium. In Section 5 we introduce the Origin Principle and also compare its out-come with the centralized or cooperative efficient equilibrium. Finally, in Section 6 we compare the outcomes obtained under the Production Principle, the Centralized Efficient equilibrium and the Origin Principle, and show under which conditions the move from the currently applied Production Principle to the Origin Principle is a Pareto improvement and should be recommended as a model solution for the European Union or other interjurisdictional entity; some avenues for further research are also provided in that section.

2. Literature

As Mechtenberg and Strausz (2006) says "the relation between mobility and human capital has for long been on the agenda of economic research". According to them, relevant literature indeed first refers to the contributions on the brain drain – see Grubel and Scott (1966) or Bhagwati and Hamada (1974). In a similar context, Justman and Thisse (1997) points out the link between mobility and underprovision of publicly provided education. By contrast Stark, Helmenstein and Prskawetz (1997), Beine, Docquier and Rapoport (2001), and Stark and Wang (2002) also consider private investment in education. More recently, both forms of financing education are taken into account by Poutvara (2004a,b). Quoting Mechtenberg and Strausz, "the most stable result established by this kind of literature is that although increasing mobility (...) will lead to higher private investment in education, public provision will decrease. The government will tend to free ride on the education system of other country". Buettner and Schwager (2004) produces a similar result while, next to free rider effect, Kemnitz (2005) also considers the competition effect for governments providing education to mobile students.

The present paper has some features in common with Mechtenberg and Strausz, especially it introduces the opportunity to become *international* and to acquire *multicultural skill*, and the probability of returning home after completing studies abroad. However it departs from that contribution by focusing on the issue of which country should be responsible for financing foreign students, regarded from the point of view of efficiency and fiscal federalism.

3. The Production Principle

According to the Production Principle, studies are financed by the host jurisdiction. This is the most popular system among jurisdictions where Higher Education is publicly funded. Elaborating in that context we first examine the demand for credits by resident students, then the supply of credits by jurisdictions and the effective numbers of credits assuming that the countries behave non-cooperatively in a decentralized setting.

A. The demand for credits

Suppose a representative student of a jurisdiction i. He decides of the credits he wants to obtain at home, n_{ii}, by comparing the private return on those credits, $f(n_{ii})$ such that $f' > 0$ and $f'' < 0$, with their opportunity cost, the wage that he can obtain if he remains, say, unskilled, w_i and, with the other extra costs related to those credits, including possible tuition fees and on or off campus boarding costs, p_{ii}; such an approach is standard in the literature. Alternatively, he may want to obtain some credits abroad, say n_{ij}, because those credits provide him with a higher return $(1+ma)f(n_{ij})$, $0<a<1$, since he becomes *international* or acquires *multicultural skill*[6]; however those credits have an extra cost $p_{ij} > p_{ii}$ that the student has to support by himself, including transportation cost and extra costs related to living abroad; m is a variable between 0 and 1 reflecting the capacity of the foreign university to actually providing the multicultural skill or of the student himself to take profit of his stay abroad to become international.

[6] One can imagine that the value of a is determined by the labor market, especially by its demand side.

His demand for credits is then such that

$$f'_{ii} = w_i + p_{ii} \tag{1}$$

and

$$(1+ma)f'_{ij} = w_i + p_{ij} \tag{2}$$

If we specify $f(x)$ as $\ln x$, those equations provide us with the demand for credit functions, assuming $w_i = w$ in both countries and $\gamma_{ij} = \gamma$ as well – that latter means that the extra costs of studying abroad, related to say transportation and accommodation, are symmetric

$$n^d_{ii} = 1/(w + p_{ii})$$

$$n^d_{ij} = (1 + ma)/(w + p_{ij}) \tag{3}$$

We do not elaborate more on the decision of either studying at home or abroad [7].

Let us add that, in line with Mechtenberg and Strausz (2006), if someone studies abroad, he has a probability R of returning home after completing his program and a probability $1 - R$ to remain in the foreign country; we call the decision to stay abroad a *sweet heart effect*.

We don't elaborate further on those issues now and we immediately turn to the supply of credits by the jurisdiction, deliberately confusing the government, the higher education authority and the university.

B. The supply for credits

Let us now turn to the government of jurisdiction i. It maximizes a Social Welfare Function defined on the future contribution to GDP of students educated at home or abroad that will be resident of jurisdiction i, net of the sacrifice in terms of immediate contribution to GDP involved by the studies of the residents and of the cost of the public funds levied to finance the production of credits; those public funds are deemed to be levied through a lump sum tax turned into a subsidy to universities, implying a cost $\lambda > 0$ per credit – on those costs in general, see Laffont and Tirole

[7] One approach is to assume that the decision as to study at home or abroad depends on the surplus generated by each opportunity. If he studies at home his surplus will amount to

$$S_{ii} = \ln(n_{ii}) - (w_i + p_{ii})\, n_{ii}$$
$$= -[\ln(w_i + p_{ii}) + 1]$$

while if he studies abroad,

$$S_{ij} = (1 + ma)\,[\ln(1 + ma) - \ln(w_i + p_{ij}) - 1]$$
$$\simeq -(1 + ma)\,[\ln(w_i + p_{ij}) + 1] + (1 + ma)\, ma$$

It turns out that, admitting the second interpretation for the m variable, the student not able to adapt to a foreign environment, thus such that $m = 0$, will never decide to study abroad. Unlike that, the student such that $m > \hat{m}\,(a, w_i, p_{ii}, p_{ij})$ will study abroad, with $\hat{m}\,(a, w_i, p_{ii}, p_{ij})$ such that $S_{ii} = S_{ij}$.

Then, if the population of domestic student is characterized by a variable m uniformly distributed between 0 and M, one can compute the demand for credits at home and abroad. Alternatively we can assume, and compute accordingly, that the type of the representative is unknown or that one representative student is of the $m < \hat{m}$ type and one of the $m > \hat{m}$ type.

(1993)[8]. Finally, let us notice p_{ji} the tuition fee possibly asked from non resident students, per unit of credit, if permitted. A variable $\theta \geq 1$ indicates that the social return on credits might be larger than the private one justifying the public good aspect of Higher Education by social externalities.

As a consequence, the Social Welfare Function of country i may be written

$$W_i = \theta f(n_{ii}^s) + R\,(1 + ma)\,\theta f(n_{ij}) + (1 - \mathrm{R})\,(1 + ma)\,\theta f(n_{ji}^s)$$
$$- \lambda\,(n_{ii}^s + n_{ji}^s) - p_{ij} n_{ij} - w\,(n_{ii}^s + n_{ij}) + p_{ji}\, n_{ji}^s \tag{4}$$

where a superscript s indicates an amount supplied; other variables refer to effective amounts i.e. possibly the minimum of supply and demand. The social planner of that jurisdiction will decide on the credits supplied to its resident students studying at home and to the foreign students it hosts

$$\theta f'_{ii} - \lambda - w = 0 \tag{5}$$

and

$$(1 - R)\,(1 + ma)\,\theta f'_{ji} - \lambda + p_{ji} = 0 \tag{6}$$

For illustrative purposes, suppose again that $f(x) = \ln(x)$. Then,

$$n_{ii}^s = \theta / (\lambda + w)$$
$$n_{ji}^s = (1 - R)\,(1 + ma)\,\theta / (\lambda - p_{ji}) \tag{7}$$

C. *The effective number of credits*

Let us first consider students deciding for studies at home, then for studies abroad.

1. *Purely domestic students*

The effective number of credits provided to the representative student deciding to study at home is, omitting unnecessary subscripts and setting $p_{ii} = p_{jj} = p$,

$$n_{ii}^P = n_{jj}^P = \min\,[1 / (w + p),\ \theta / (\lambda + w)] \tag{8}$$

Two cases then arise. On the one hand, the equality between supply and demand can be realized if a tuition is imposed which amounts to

$$p = \frac{\lambda - (\theta - 1)\,w}{\theta} \tag{9}$$

Especially, if there is no social externality *($\theta = 1$)*, $p = \lambda$ so that the equilibrium tuition fee required from local students exactly offsets the cost implied by a subsidy to the university financed through a lump sum tax, or by other system involving inefficiencies. If a social positive externality exists, $\theta > 1$ and $p < \lambda$ since

$$\frac{dp}{d\theta} = -\frac{\lambda + w}{\theta^2} < 0 \tag{10}$$

[8] Notice that we can easily enlarge the application of the model to partly privately funded Higher Education; then λ includes the social cost of the imperfection of the capital market.

That expression shows that part of the cost is offset by the positive externality. Alternatively we can say that the cost λ decreases when either the tuition fee or the externality goes up, or if both increase.

On the other hand, if the tuition fee needs to vanish, an extreme case for a publicly funded university, $p = 0$ and there is an excess demand or an excess supply depending on

$$\theta \gtreqless (\lambda + w) / w \tag{11}$$

In the sequel we realistically suppose θ and λ such that there is an excess demand. That will be the case for sure if $\theta = 1$. As a consequence the effective number of credits supplied to local students amounts to $\theta / (\lambda + w)$.

2. Foreign students

Similarly the effective number of credits provided to students deciding for studies abroad amounts to, omitting again unnecessary subscripts and setting $p_{ij} = p_{ji} = p_f + \gamma$.

$$n_{ij}^P = n_{ji}^P = \min \left[(1 + ma) / (w + p_f + \gamma) \, , \, (1 - R)(1 + ma)\, \theta / (\lambda - p_f - \gamma)\right] \tag{12}$$

Again, two cases arise. On the one hand, the equality between supply and demand can be realized if a tuition is imposed to foreign students which amounts to

$$p_f = \frac{(\lambda - \gamma) - (1 - R)\, \theta\, (w + \gamma)}{(1 - R)\, \theta + 1} \tag{13}$$

Especially, if there is no social externality ($\theta = 1$), foreign students go back home after completing their studies ($R = 1$) and $\gamma = 0$, then again $p = \lambda$ so that the equilibrium tuition fee required from foreign students also exactly offsets the cost implied by the financing of the provision of the credit by the publicly funded university. Unlike for domestic students, in case of positive social externality the tuition fee rebate only appears when the probability that foreign students go back home departs from unity, and is proportional to $1 - R$. Thus, for $\gamma = 0$,

$$\frac{dp_f}{d\theta} = - \frac{1 - R}{[(1 - R)\, \theta + 1]^2} \; \frac{\lambda + w}{\theta^2} < 0 \tag{14}$$

and the decline of the equilibrium tuition fee with respect to the size of the externality is smaller. As a consequence, the equilibrium tuition fee to be charged to foreign students, if permitted, should be larger. Then,

Proposition 1 *When students are mobile across borders, jurisdictions are symmetric and decisions are taken in a decentralized way, if the cost of higher education is supported by the production jurisdiction exclusively, the efficient equilibrium tuition fee charged to foreign students should be larger than that charged to local students, the discrepancy depending a.o. on the probability of foreign students returning home after completing their studies abroad.*

That proposition highlights e.g. the behavior of US States or some Canadian provinces charging a larger fee to non-state or non-province residents in State or Province funded universities.

On the other hand, if the tuition fee needs to vanish for foreign students as well as to domestic students, an extreme case for non-discrimination between resident and non-resident students[9], $p_f = 0$ and there is an excess demand or an excess supply depending on

$$(1 - R)\,(w + \gamma)\,\theta \lesseqgtr \lambda - \gamma \tag{15}$$

In the sequel we suppose θ, R and λ such that there is an excess demand. That will be the case if $\theta = 1$, $\gamma = 0$ and R close to unity [10]. As a consequence the effective number of credits served to foreign students amounts to $(1 - \mathrm{R})\,(1 + ma)\,\theta \,/\, (\lambda - p_f - \gamma)$.

D. *Free riding its neighbor*

Let us still investigate what happens if a jurisdiction exports a student and re-imports him after he has completed his curriculum [11]. Therefore consider again equation (4), then the effect on the Social Welfare of his jurisdiction of origin is given by

$$dW_i = R\,(1 + ma)\,\theta f'_{ij} - \theta f'_{ii} + \lambda - p_{ij} \tag{16}$$

The right hand side of that expression might be positive. In particular it is more likely to be positive when the probability R of the students to return home after completing their studies is high – which is consistent with observation in the EU –, when the valuation a of studies abroad and the capacity m of the students to take profit of that value increase – which is *per se* an incentive for local university to be of bad quality, a logically going up with the difference in quality, and when the cost of studying abroad decreases – specially if the tuition fee abroad is small, say p_f is zero, and cost of living abroad is also small, say again γ vanishes. Notice that due to the shape of the return function, as long as less credits are obtained abroad than at home, $f'_{ij} > f'_{ii}$.

It turns out that

Proposition 2 *When students are mobile across borders, jurisdictions are symmetric and decisions are taken in a decentralized way, if the cost of higher education is supported by the production jurisdiction exclusively, no price discrimination against foreign students is permitted and those students are likely to return home after com-*

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[9] Notice that if price discrimination is not allowed within the EU with respect to citizen from other EU Member States, some jurisdictions discriminate using quantity rationing, e.g. in French-speaking Belgium by a drawing among the numerous foreign students – especially from France – who want to study in that part of Belgium.

[10] Mansoorian and Myers (1993) write, in the context of their study, that “individuals derive non-pecuniary (psychic) benefit from living in their home”. They see that as something “of special interest for systems that consist of culturally diverse regions, such as the EEC and Canada”. “In such systems, they add, it would be reasonable to assume that individuals would have a preference for a particular region for cultural (...) reasons”.

[11] See footnote 4.

pleting their studies abroad, jurisdictions have an inventive to free ride their neighbor and to produce poor quality studies.

4. The Centralized Solution: efficient number of credits obtained abroad

Suppose now a central planner maximizing the sum of the two social welfare functions. Then the first order conditions imply

$$\theta f'_{ii} - \lambda - w = 0 \tag{17}$$

unchanged, but

$$R\,(1 + ma)\,\theta f'_{ji} + (1 - R)\,(1 + ma)\,\theta f'_{ji} - \lambda - w = 0 \tag{18}$$

so that, in our illustration

$$n^C_{ii} = n^C_{jj} = \theta\,/\,(\lambda + w)$$

$$n^C_{ij} = n^C_{ji} = \min\,[(1 + ma)\,/\,(w + p_f + \gamma)\,,\,(1 + ma)\,\theta\,/\,(\lambda + w)] \tag{19}$$

and comparing the supply of credits in a centralized setting with that observed above for a decentralized setting when the Production Principle is at work,

$$n^C_{ij} = n^C_{ji} > n_{ij} = n_{ji} \tag{20}$$

Especially, if no (discriminatory) fee may be required from EU foreign students, and given our assumptions on θ, R and λ

$$n^C_{ij} = (1 + ma)\,\theta\,/\,(\lambda + w) > (1 - R)\,(1 + ma)\,\theta\,/\,(\lambda - \gamma) = n^P_{ij} \tag{21}$$

We summarize that discussion by issuing

Proposition 3 *When students are mobile across borders, jurisdictions are symmetric and decisions are taken in a decentralized way, if the cost of higher education is supported by the production jurisdiction exclusively, no price discrimination is allowed among students and those students are much likely to return home after completing their studies, the number of credits obtained abroad is inefficiently low.*

The reason is the following: when the social planner of jurisdiction i increases the number of students it hosts, it generates a positive externality in the other jurisdiction. That positive externality is taken into account by the central planner.

5. The Origin Principle

Now the country of residence or origin of the student – in this context we can use those terms indifferently although the use of the latter is probably better: in the US a student originated from one state who studies in another state may be considered as a resident of that other state after completing his first year of studies and then only charged with the reduced fee for residents of the state – needs to pay for their studies abroad, through e.g. the provision of portable vouchers.

For that purposes, let v_i stand for the voucher per credit provided to his resident students by the government of country i and similarly v_j that provided by the government of country j; for simplicity we assume that $v_i = v_j$.

The demand for studies at home and abroad by resident students by country i is unchanged, still provided by equations (1) and (2); the value of the vouchers does not enter those equations since the student is only the instrument transferring that value from one institution (his home government) to another institution (the university at home or abroad, hold here for simplicity as a branch of the respective governments).

However, the Social Welfare Function of country $\underline{i}$ now becomes

$$W_i = \theta f(n^s_{ii}) + R\,(1 + ma)\,\theta f(n^s_{ij}) + (1 - R)\,(1 + ma)\,\theta f(n^s_{ji})$$
$$- \lambda\,(n^s_{ii} + n^s_{ij}) - \gamma n^s_{ij} + (\gamma + v)\,n_{ji} - \mathrm{w}\,(n^s_{ii} + n^s_{ij}) \qquad (22)$$

where the distribution of the superscripts $\underline{s}$ is now changed. Notice that λ can be reinterpreted as the cost of a portable voucher $\underline{v}$ granted to students originating in the jurisdiction and financed through a lump sum tax; in other words, we suppose that the value of the voucher exactly matches the cost of studies in both jurisdictions. The main differences between the two social welfare functions are depicted thereafter.

First, as previously, the local social planner decides of the number of credits that will be supplied at home to its resident students

$$\theta f'_{ii} - \lambda - w = 0 \qquad (23)$$

or, using the same specification as above,

$$n^s_{ii} = \theta / (\lambda + w) \qquad (24)$$

so that the effective number of credits obtained at home by residents of i is

$$n^O_{ii} = n^O_{jj} = \min\,[1 / w,\, \theta / (\lambda + w)] = \theta / (\lambda + w) \qquad (25)$$

Second, unlike previously, the government of country $\underline{i}$ now no longer decides on the number of credits that it supplies to foreign students – it will supply any number since it does not support the cost –, but it decides on the number of credits obtainable abroad by its residents that it finances, n^s_{ij}

$$R\,(1 + ma)\,\theta f'_{ij} - \lambda - w - \gamma = 0 \qquad (26)$$

or

$$n^s_{ij} = R\,(1 + ma)\,\theta / (\lambda + w_i + \gamma + v) \qquad (27)$$

so that

$$n^O_{ij} = n^O_{ji} = \min\,[(1 + ma) / (w + \gamma)\,,\, R\,(1 + ma)\,\theta / (\lambda + w + \gamma)]$$
$$= R\,(1 + ma)\,\theta / (\lambda + w + \gamma) \qquad (28)$$

Since $R < 1$, when the Origin Principle applies in a decentralized setting, the number of credits obtained abroad is still smaller than its efficient level, given by equation (21).

Therefore,

Proposition 4 *When students are mobile across borders, jurisdictions are symmetric and decisions are taken in a decentralized way, if the cost of higher education is supported by the origin of the students jurisdiction exclusively, no price discrimination is allowed among students and those students are much likely to return home after completing their studies, the number of credits obtained abroad is inefficiently low.*

Again the economic intuition is simple: when jurisdiction $\underline{i}$ decides to send an additional student abroad it generates a sweet heart effect in the other jurisdiction, which amounts to $(1 - R)\,(1 + ma)\,\theta f'$.

However, this effect is now accompanied by a tax effect $-\lambda$ in its own jurisdiction due to the transfer to the university of the other jurisdiction. And notice that the counterpart of equation (16) is now

$$dW_i^O = (1 + ma)\,\theta\,R f'_{ij} - \gamma - \theta f'_{ii} < (1 + ma)\,\theta\,R f'_{ij} - \gamma - \theta f'_{ii} + \lambda = dW_i^P \qquad (29)$$

so that country i has less incentive to free ride its neighbor.

6. Tentative conclusion and proposition

Comparing all these situations for the case of entirely publicly funded Higher Education, we have that

$$n_{ii}^P = n_{ii}^O = n_{ii}^C = \theta / (\lambda + w) \qquad (30)$$

and

$$\begin{aligned} n_{ij}^P &= (1 - R)\,(1 + ma)\,\theta / (\lambda - \gamma) \\ < n_{ij}^O &= \mathrm{R}\,(1 + ma)\,\theta / (\lambda + w + \gamma) \\ < n_{ij}^C &= (1 + ma)\,\theta / (w + \lambda) \end{aligned} \qquad (31)$$

and similarly for country j, again ignoring p. The first part of the above ranking holds if

$$\frac{R}{1 - R} > \frac{\lambda + w + \gamma}{\lambda - \gamma} \qquad (32)$$

which requires that the probability of returning home after getting his degree be large enough.

We then conclude that

Proposition 5 *When students are mobile across borders, jurisdictions are symmetric, decisions are taken in a decentralized way, no price discrimination is allowed among students and those students are much likely to return home after completing their studies, moving from a system where the cost of higher education is supported by the production jurisdiction exclusively, to a system where that cost is supported by the origin of students jurisdiction, also exclusively, is a Pareto improvement.*

From a policy point of view, it turns out that charging the country of origin of the students to be responsible for organizing the payment for their studies abroad, through e.g. portable vouchers, is a second best solution, being the less inefficient between the two solutions considered so far. Nevertheless it is less efficient than the centralized outcome, the difference being the price to pay for the respect of subsidiarity principle at the root of e.g. the European Union.

Although the result stressed in this paper, in our opinion, deserves discussion among policy makers, further research might be needed as to the best way of financing Higher Education in an area like the European Union. Especially the model used in this paper should be expanded in order to explicitly take into account a larger contribution by the students themselves, including through contingent loans, or by the private sector. Another issue to be investigated is that of the consequences of the fact that, in a progressively integrating area like the European Union, it is likely that some mobile students – even if for most of them the probability to return home after completing their studies will remain large, for a long time – will stay in a jurisdiction other than their country of origin and their country of higher education; for those students, the social positive externality generated by their education will benefit a third country and the issue arises of how to have that third country contributing to the financing of the human capital it benefits from. There is room for a specific design that should be close to the centralized solution but compatible with the subsidiarity principle. In that respect empirical investigation of the functioning of Higher Education in various modern federations could be helpful.

Let us add two final remarks. First, links should be investigated with incentives to specific kinds of studies and *numerus clausus* which may be desirable in some professions. Actually the institutional mechanism investigated above is especially designed for enlarging the field of application of that latter issue: through deciding on the allocation of study specific vouchers to students from its territory, a government may rule the local entry in specific professions in a more efficient way than with barriers to the access to the sole local schools; indeed it also limits access to similar studies abroad.

Second, we should come back to the relation with quality since the system designed above requires that portable vouchers financed by a given government should only be used in universities and other higher education institutions whose quality has been recognized, e.g. by a certification.

References

AHUES M. (2005), "Bologna: Learning the French case through an example", a paper presented at the conference on Higher Education, Multijurisdictionality and Globalization, Mons, Dec. 14-15, 2005.

BACHE I. (2006), "The Europeanization of Higher Education: Markets, Politics or Learning", *Journal of Common Market Studies*, 44, pp. 231-248.

BEINE M., F. DOCQUIER and H. RAPOPORT (2001), "Brain Drain and Economic Growth: Theory and Evidence", *Journal of Development Economics*, 64, pp. 275-289.

BHAGWATI J. and K. HAMADA (1974), "The Brain Drain, International Integration of Markets for Professionals and Unemployment", *Journal of Development Economics*, 64, pp. 275-289.

BUETTNER T. and R. SCHWAGER (2004), "Regionale Verteilungseffekte der Hochschulfinanzierung und ihre Konsequenzen" In: W. Franz, H. J. Ramser, M. Stadler, *Bildung*, 33. Wirtschaftswissenschaftliches Seminar Ottobeuren,Tubingen.

DEL REY E. (2001), "Teaching versus Research: A Model of State University Competition", *Journal of Urban Economics*, 49, pp. 356-373.

GÉRARD M. (2006a), "Enseignement supérieur et mobilité, l'interpellation du passager clandestin" In: M. Gérard et V. Vandenberghe (Eds.), "L'enseignement supérieur après Bologne", *Reflets et Perspectives de la vie économique*, 45(2), pp. 83-89.

GÉRARD M. (2006b), "Le financement des études supérieures transfrontalières", *Revue d'Economie Politique*, 116(6), pp. 789-796.

GÉRARD M. (2008), "Higher Education, Mobility and the Subsidiarity Principle", In: G. Gelauff, I. Grilo and A. Lejour (Eds.), *Subsidiarity and Economic Reform in Europe*, Springer-Verlag, Berlin Heidelberg, pp. 97-112.

GRUBEL H. and A. D. SCOTT (1966), "The International Flow of Human Capital", *American Economic Review*, 56, pp. 268-274.

JUSTMAN, M. and J.-F. THISSE (1997), "Implications of the mobility of skilled labor for local public funding of higher education", *Economic Letters*, 55, pp. 409-412.

KEMNITZ A. (2005), "Educational Federalism and the Quality Effects of Tuition Fees", a paper presented at the conference on Higher Education, Multijurisdictionality and Globalization, Mons, Dec. 14-15, 2005.

LAFFONT J.-J. and J. TIROLE (1993), *A Theory of Incentives in Procurement and Regulation*, MIT Press.

MANSOORIAN A. and G. MYERS (1993), "Attachment to home and efficient purchases of population in a fiscal externality economy", *Journal of Public Economics*, 52, pp. 117-132.

MECHTENBERG L. and R. STRAUSZ (2006),"The Bologna Process: How student mobility affects multi–cultural skills and educational quality", a paper presented at the conference on Higher Education, Multijurisdictionality and Globalization, Mons, Dec. 14-15, 2005.

POUTVAARA P. (2004a), "Educating Europe: Should Public Education be Financed with Graduate Taxes or Income-Contingent Loans?", *CESifo Economic Studies*, 50(4), pp. 663-684.

POUTVAARA P. (2004b), "Public Education in an Integrated Europe: Studying to Migrate and Teaching to Stay?", *CESifo Working Paper* No. 1369.

SAPIR A. *et al*. (2003), *A Agenda for a growing Europe, Making the EU Economic System Deliver*, European Commission, Brussels.

STARK O., C. HELMENSTEIN and A. PRSKAWETZ (1997),"A Brain Gain with a Brain Drain", *Economic Letters*, 55, pp. 227-234.

STARK O. and Y. WANG (2002), "Inducing Human Capital Formation: Migration as a Substitute for Subsidies", *Journal of Public Economics*, 86, pp. 29-46.

VAN DER PLOEG F. and R. VEUGELERS (2008),"Higher Education Reform and the Renewed Lisbon Strategy: Role of Member States and the European Commission", In: G. Gelauff, I. Grilo and A. Lejour (Eds.), *Subsidiarity and Economic Reform in Europe*, Springer-Verlag, Berlin Heidelberg, pp. 65-96.

Regulation of program supply in higher education
Lessons from a funding system reform

Stijn Kelchtermans and Frank Verboven[1]

Summary

It has become well documented that the performance gap between European and US universities is at least partly due to lower spending on higher education in Europe. Rather than raising the public budget or promoting private contributions, many governments have attempted to make public spending more efficient in various ways. This paper reports on results from a proposed funding system reform in Flanders (Belgium), which aimed to save costs by reducing the diversity and duplication of study programs. We draw the following lessons. While reducing program diversity may save on fixed costs, this is typically insufficient to compensate for consumer surplus losses due to low student mobility. Furthermore, decentralized financial incentives mechanisms may be ineffective since they may often promote program cuts when this is undesirable, and vice versa. These findings illustrate the difficulties with regulatory reforms that mainly aim to reduce costs. Hence, the question how to raise total spending on higher education (whether through public or private means) cannot be avoided.

1. Introduction

There is a growing awareness that European universities are lagging behind and are in need for reform. For example, in a recent policy brief Aghion *et al.* (2007) find that the performance gap between European and US universities is due to poor governance and incentives, but also due to insufficient investment in higher education. Total public and private spending on higher education amount to only 1.3 % of GDP in the EU, compared with 3.3 % in the US. Most European governments have not yet succeeded in promoting a substantial increase in higher education spending.

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On the one hand, because of tight government budgetary constraints, it is unrealistic to drastically expand public spending on higher education. On the other hand, politicians in many countries still show a reluctance to promote private contributions through tuition fees.

As an alternative, some governments have attempted to increase the efficiency of the public funding systems. An example is the case of Flanders (Belgium), where the government has recently encouraged mergers and formal collaboration agreements, and attempted to provide incentives to institutions to reduce the large diversity and duplication of study programs. According to the 2005 proposals, institutions would receive public funding based on their achieved concentration index, i.e. the average number of students per program, thereby providing incentives to cut the smaller programs. Furthermore, funding incentives were proposed to offer joint programs between universities. The idea behind these proposals was to provide decentralized incentives to make the higher education system more cost efficient, hence reducing the need to expand the overall public budget. However, while there may indeed be cost savings from increased scale and less duplication of supply, this is only part of the welfare picture. It is also necessary to take into account how students will be affected by changes in the supply of higher education.

This paper reports on the findings in Kelchtermans and Verboven (2007) to draw some general lessons on social desirability and the effectiveness of funding system reforms that attempt to reduce program diversity. They develop a model to estimate both the profit and welfare effects of reducing program diversity, including the effects on consumer surplus (students), variable and fixed cost savings. They find that the social desirability of reducing diversity is limited to only 10 % of the programs, because students show a limited willingness to travel to other institutions. The fixed cost savings from program cuts are thus usually too limited when compared with the consumer surplus losses. Kelchtermans and Verboven also find that a funding system based on the concentration index may be very ineffective: it frequently creates incentives to cut programs when this would be socially undesirable, and vice versa. This stresses that decentralized mechanisms should be chosen with care if they are to achieve the intended objectives.

More generally, these findings emphasize the complexities in regulating program diversity in publicly financed systems of higher education. Governments need to take into account both the universities' and the students' responses to their policies. In this light, no magical solutions can be expected from policies that aim to reduce costs. So the question how to raise total spending on higher education (whether through public or private means), cannot be avoided.

The remainder of this paper is organized as follows. Section 2 discusses the cross-country evidence available from the academic literature on diversity in higher education. It also discusses current program diversity in Flanders in this international context. Section 3 discusses international policies towards program supply and diversity, and then describes the recent Flemish reform proposals. Section 4 provides an economic framework for analyzing program diversity in higher education, stressing the importance of trading off both the benefits and costs. Section 5 summarizes the profit incentives and welfare effects of the funding system reforms in Flanders aimed at reducing program diversity, based on the methodology and detailed analysis in Kelchtermans and Verboven (2007). Finally, Section 6 concludes and draws more general lessons on reform.

2. Previous evidence on diversity

Most of the literature has been preoccupied with defining and measuring diversity in higher education. This has resulted in a number of comparative studies documenting the evolution of diversity in several countries. We first review this literature and then discuss current program diversity in the region of our case study, Flanders (Belgium).

A. International context

Dill and Teixeira (2000) distinguish between institutional diversity and program diversity [2]. Institutional diversity refers to diversity among institutions in size (number of students), in mission, in type of control (public versus private), and in location. Program diversity refers to diversity in subject, in degree level (bachelor versus master), in orientation (academic versus vocational), and in forms of program delivery (e.g. full-time, part-time, distant learning). According to Dill and Teixeira (2000), the term diversity often refers to institutional diversity in the US and to program diversity in Europe.

An influential early study on the evolution of diversity in the US is Birnbaum (1983). His composite indicator includes the institution's size, institutional control (public or private), enrollment of females and minorities, program types and degree levels. He therefore considers elements of both institutional and program diversity.

Several other studies focus exclusively on program diversity. For example, Ben-David (1972) looks at the number of new programs created in the US and Germany between 1900 and 1930. He finds that both countries started of with a similar number of programs but the US has a much higher number in 1930 because of the stronger competition between universities in the US. Huisman and Jenniskens (1994) compared the evolution of study programs and their locations in Denmark, Germany and the Netherlands; Jenniskens (1997) considers the evolution of new programs in the Netherlands, France, England and Pennsylvania. Huisman and Morphew (1998) study the evolution of program diversity in the Netherlands and various US states, using the ratio of duplicate programs to the total number of programs. Their findings suggest that program diversity is low because institutions tend to copy the programs of leading institutions.

More recent and complete cross-national evidence is provided by Huisman, Meek and Wood (2007). Following Birnbaum (1983) and several others, they define diversity based on the following variables: the institution's size, institutional control, range of disciplines offered, degrees awarded and modes of study. They find that the group of countries with most diversity in higher education consists of the United Kingdom, Flanders and the Netherlands. Finland, Germany and Austria belong to the second group. The group with the lowest diversity consists of Sweden, France, Den-

[2] The literature review in this section draws extensively on Dill and Teixeira (2000).

mark and Australia. Overall, the authors conclude that even the countries in the third group show a large degree of diversity, so that there is currently no need to encourage diversity further, except perhaps in some specific areas. The authors also performed a longitudinal analysis for Australia and the Netherlands and caution that some recent mergers may entail the risk of being counterproductive in reducing diversity.

To summarize, there is quite an extensive descriptive literature documenting diversity in higher education. This literature is mainly motivated by a concern whether diversity is sufficiently high. This is in stark contrast with Flanders where policy makers' concern is the opposite: they consider the high diversity of the Flem-

Table 1 Diversity of higher education in Flanders (2001)

	Number of campuses	*Number of study programs*	*Number of students*	*Students/ study program*
	Colleges (vocational programs)			
Total	44	414	25,182	61
by study field				
Architecture	9	11	912	83
Engineering	25	76	4,425	58
Science	n/a	n/a	n/a	n/a
Economics and Business	22	105	7,853	75
Education Science	26	67	6,065	91
Other Social Sciences	13	15	1,572	105
Medicine and Paramedics	23	54	1,904	35
Bio-engineering	15	26	644	25
Languages	5	5	738	148
Cultural Studies	10	55	1,069	19
	Universities (academic programs)			
Total	9	148	12,299	83
by study field				
Architecture	3	3	198	66
Engineering	3	3	834	278
Science	7	33	1,169	35
Economics and Business	7	12	1,700	142
Education Science	3	6	711	119
Other Social Sciences	6	19	3,701	195
Medicine and Paramedics	6	19	933	49
Bio-engineering	6	13	1,177	91
Languages	6	17	842	50
Cultural Studies	6	23	1,034	45

Own calculations based on a dataset from the Flemish Ministry of Education. The first column counts the number of campuses offering at least one study program of a given study field. The second to fourth column show averages over all study programs of a given study field.

ish system [3] as an indication that there may be excess diversity, as discussed in more detail in Section 3, B.

B. Program diversity in Flanders

Table 1 describes the diversity of first-year undergraduate higher education in Flanders in 2001. There are two types of institutions: colleges ("*hogescholen*") and universities. There are 44 college campuses and 9 university campuses. Given the small size of Flanders this amounts to a high density of one campus per 250 km^2.

The colleges offer a total of 414 vocational programs, and the universities a total number of 148 academic programs. There is considerable duplication of program supply since most fields and programs are broadly available at multiple campuses across the region. This is particularly true for vocational fields such as engineering, economics and business, education science, and medicine, all offered at more than 20 campuses throughout Flanders. The average scale per program is correspondingly low, usually less than 100 incoming students per program at colleges and between 50 and 200 per program at universities.

A key question is whether this level of program diversity is too low or too high. The recent policy reforms aiming to cut diversity (to be discussed below) suggest the level of diversity is too high. From an economic perspective, however, the answer is not clear. It depends on various factors, including student preferences (mobility), and the variable and fixed costs of providing program diversity.

3. Funding policies towards diversity

Governments in different countries have followed a wide range of different policies towards higher education. Jongbloed and Koelman (2000) classify the higher education funding systems according to two dimensions, see Figure 1. The first dimension (horizontal axis) describes to what extent funding is allocated based on output or input criteria (outcoming versus incoming students). The second dimension (vertical axis) describes the extent of direct government control over the funding arrangements. This dimension is most relevant for our purposes. It ranges from heavily centralized, regulated systems to decentralized, market-driven systems. At the one extreme, we find public funding systems of bilateral negotiated funding (strong central control) while at the other end of the spectrum we find market-oriented approaches such as voucher systems. In reality, funding systems will combine different funding instruments and it is not straightforward to unambiguously classify them as centralized or decentralized. Generally speaking there has been a common trend towards more decentralization, with more autonomy for institutions. This partly follows from the fact that higher education has turned into a mass market, making the funding problem too complex for a central planner (Barr, 2004).

Our interest here is in one specific and important aspect of government control over funding arrangements: the regulation of program supply and diversity. We first

[3] This is considered common wisdom but is also supported by studies such as Huisman, Meek and Wood (2007).

discuss differences in policies towards program regulation in several countries, and then describe the policy and recent reforms in Flanders.

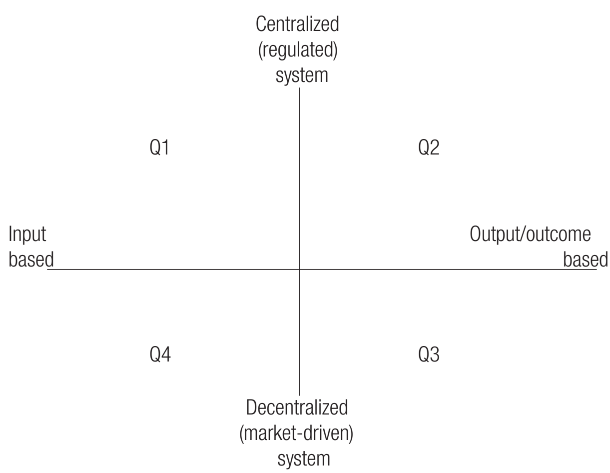
A. *International context*

Governments typically intervene in public systems of higher education by providing subsidies to universities and regulating tuition fees. At the same time, governments intervene by regulating program supply, since otherwise institutions would have distorted incentives for the sake of obtaining the subsidies.

The regulation of program supply is therefore a crucial aspect of government policy intervention, but there has been fairly little comparative research on the different approaches followed in different countries. To our knowledge, Huisman *et al.* (2003) provide the only detailed cross-country comparison. To put the regulation of program supply in the Netherlands in perspective, they consider the situation in several other systems: Australia, Denmark, Finland, Flanders, Scotland. They look at the regulations on how to set up new programs and at the quality control of existing programs. They summarize their findings by classifying the countries according to the extent of government control (the vertical dimension of Jongbloed and Koelman's framework, see Figure 1). They come up with three different groups of countries.

— Flanders and the Netherlands are characterized by strong government involvement in program supply decisions. Educational authorities put forward a number of quality requirements before an institution is allowed to offer a new program. In addition, the Flemish government applies "macro-efficiency criteria" such as the societal relevance of the program, the relation with existing supply, and the potential demand for the program.

Figure 1 Classification of public funding regimes (Jongbloed & Koelman, 2000)



— In Denmark and Finland, the extent of government control is more limited. For example, in Finland, the establishment of a new program requires the approval from the Ministry of Education, but the universities have the freedom to decide on its content. Government control is rather performance-based, by means of a contract with the institution specifying targets such as the number of graduates.
— In Scotland and Australia, the government hardly interferes in program supply, and only indirectly so. The higher education institutions are themselves responsible for their supply decisions. Instead of judging requests of institutions to set up new programs, a maximum number of fundable student places per study field is set, which acts as an incentive for the institutions to organize their supply in an efficient way.

Note that the Flemish system is the only one using macro-efficiency criteria in its supply regulation policy. Although this seems a sensible thing to do, our analysis will show that a formal welfare analysis allows a more precise answer to program diversity questions than the currently used criteria of efficiency and transparency.

In sum, this brief review shows that government control over program supply and diversity shows a lot of variation across countries. Flanders is one of the heavily regulated countries during the time of Huisman *et al*. study in 2003. We now turn in more detail to the case of Flanders, in particular its recent funding system reform proposals.

B. *The recent funding system reform in Flanders*

The Flemish government intervenes by regulating tuition fees, currently uniform at €425 for colleges and €445 for universities, and subsidizing the higher education institutions. The subsidies consist of a fixed component (independent of the number of students) and a variable component, a constant amount per student (specific per program field).

At the same time, the Flemish government intervenes heavily in the quality and diversity of program supply. The quality is controlled through a system of self-assessments and external visiting committees. The diversity is regulated since institutions are not automatically eligible to offer all possible study programs. In practice, however, the institutions form a continuous pressure to be entitled to supply additional programs and attract additional subsidies through the enrolled students. As discussed in Section 2, B, this has resulted in a large program diversity, relative to other countries, with 562 programs offered across 53 institutions in the academic year 2001-2002 (see Table 1).

The 2005 reform proposals aimed to make the funding system more efficient. The constant subsidy per student has been made in line with recent and more accurate estimates of the variable cost per student, as obtained by Deen *et al*. (2005) for various programs and fields. The subsidies per student tend to be lower for colleges than for universities, and lower for humanities and social sciences than for medical and exact sciences.

The more crucial 2005 part of the reform proposals, and the focus of our analysis, consisted of a series of financial incentives to induce institutions to limit the number of institutions and programs. These decentralized incentives served as an alternative to the former approach which had unsuccessfully attempted to limit product diversity through direct government control [4, 5]. There were three main measures to cut program diversity. First, institutions were required to reach a minimum size to be eligible for funding. Second, there were financial bonuses through phase-out funding for programs that an institution decided to cut; institutions could also earn additional funding by jointly offering study programs. The third incentive proposed to reduce product diversity was the replacement of the fixed funding component by a variable scheme based on the institutions' achieved concentration index.

The concentration index of an institution k, C_k, is the average number of students per offered study program:

$$C_k = \frac{Q_k}{J_k}$$

where Q_k is the total number of students and J_k is the total number of study programs at institution k. An institution would then receive a subsidy amount r per unit of the achieved concentration index [6]. We will refer to this system as the CI funding system. It provides an incentive to reduce the number of programs J_k, though at the risk that the number of students Q_k also goes down. We come back to the effect of the concentration index in more detail in Section 4, D.

Although the concentration index still relies on student counts, the use of formula-based funding rather than negotiated funding clearly represents a decrease in direct government control.

In the remainder of the paper we will address the following questions regarding the Flemish higher education system:

1) Is reducing current program diversity socially desirable?
2) Does the decentralized CI funding system provide incentives to reduce diversity whenever this is socially desirable?

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[4] During a previous legislation (i.e. prior to the 2005 reforms discussed here), the Minister of Education commissioned former KU Leuven rector Dillemans to work out a plan to optimize higher education supply, which was proposed in 1997. These efforts were not very successful, in part because the government used "soft" instruments such as consultation with the higher education sector. The next Minister of Education (1999) relieved Dillemans of his tasks and shortly after that the policy debate became dominated by the introduction of the Bachelor-Master structure and overshadowed the plans for the one-shot optimization envisaged in Dillemans' plan. The latest government (2004) showed attention again to optimize supply diversity, in the context of the funding system reforms we are discussing here.

[5] Next to these incentives aimed at optimizing supply, the funding system reform stepped away from pure input-financing and now includes students' success (in terms of acquired credits) as a criterion of funding. In terms of the funding system classification presented in Figure 1, the reforms therefore represent a move towards not only increased decentralization but also more output-orientation. It is generally recognized that the use of an output-based funding policy may raise concerns of deteriorating educational quality if not accompanied by quality assurance mechanisms. A nice example is provided in the paper by Bagües, Sylos Labini and Zinovyeva (2007) who analyze the impact of the adoption of such a policy in Italy on universities' grading standards.

[6] In practice, the index is slightly more complicated (Vandenbroucke, 2005). It is normalized by the average index over all institutions. Further, this normalized concentration index is constrained within bounds of 0.5 and 1.5. We account for this in our empirical analysis, but not in our discussion since it complicates the exposition and it only matters for a minority of the institutions. The lower bound is obtained for 5 and the upper bound for 4 out of the 53 institutions.

In essence, the second question asks whether an all-in-all modest adaptation of the funding regime is able to create the right incentives and improve efficiency without relinquishing public control of the higher education system. We note, however, that the 2005 proposed CI funding system was not actually incorporated in the 2007 reforms for practical reasons [7]. Nevertheless, our analysis of the proposed reforms remains of general interest, since it will emphasize the key importance of properly accounting for students' demand responses. It is therefore also relevant for other financial incentive schemes designed to reduce product diversity (such as the financial bonuses to eliminate or merge study options).

4. Economic framework

Despite the policy importance, there has been only limited literature on the benefits of diversity in higher education, and even less on the associated costs. The empirical literature documenting diversity as reviewed in Section 2, A tends to start from an implicit presumption that more diversity is always better. To evaluate diversity, there is clearly a need for a transparent economic framework that clarifies the potential objectives of policy makers, and considers both the benefits and the costs. This section provides such a framework, and applies it in the next section borrowing from the more elaborate analysis in Kelchtermans and Verboven (2007).

We first discuss the effects of diversity on participation, and subsequently the effects on total welfare (which trades off the monetary benefits and costs). We next ask whether the existing market structure is likely to provide too much or too little diversity from a total welfare perspective, and finally consider the effects of the funding system reform in Flanders regarding diversity.

A. Participation

To our knowledge, the only available literature on the economic effects of diversity in higher education relates to the effects on participation. Trow (1972) was an important early author on this issue. He argued that greater diversity was essential for the growth to massification in higher education. As discussed by Huisman, Kaiser and Vossensteyn (2000), this hypothesis is based on the presumption that increased diversity implies more choice and therefore increased the chances to participate. They test this hypothesis based on a cross-section of nine European countries. They construct measures of participation and diversity for each country, and measures for other variables that may affect participation (financial incentives and selection). They find no support for Trow's hypothesis: there is no positive relationship between high diversity and participation. If anything, the relation is negative. For example, France shows a low diversity yet a high participation rate, whereas the United Kingdom and Flanders have a high diversity and a relatively low participation rate.

This conclusion is consistent with our own research for Flanders (Kelchtermans and Verboven, 2006). We estimated a logit model of educational choice at the level

[7] For example, it was argued by universities that it is common to pool students and share them across study programs so that critical mass is achieved whilst the concentration index is not able to capture such initiatives.

of potential new students deciding whether to pursue higher education. We found that the travel costs and program availability did not significantly affect the decision whether to participate, but only the decision at which institution to study and which program to take.

Combining these findings, we will henceforth assume that modest variations in program diversity have no significant effects on participation in higher education. This is not to say that large changes in program diversity would not have significant effects, which is perhaps what Trow originally suggested.

B. Total welfare

Economic theory has long been interested in the question whether alternative market structures, such as monopoly or free entry, can generate the socially optimal level of product diversity [8]. To address this question, it is necessary to first define total welfare. Total welfare in the market of higher education is approximately equal to:

— *gross consumer surplus*, i.e. the students' total willingness to pay;
— *minus total variable costs* of providing higher education;
— minus *total fixed costs*.

Note that this definition of total welfare entails some simplifications. First, this welfare definition abstracts from income effects and distributional considerations. In reality, a social planner may want to put a higher weight on low income groups to obtain a fair distribution. Second, the government pays subsidies to the institutions. The welfare definition does not include these since they merely transfers. However, there may be social costs of public funds (e.g. because of distortionary taxes required to finance the subsidies). In this case, a fraction of the paid subsidies would have to be subtracted from the welfare definition. Third, the gross consumer surplus refers to the students' private benefits from higher education and the welfare definition assumes that these coincide with the social benefits. In reality, the social gains from higher education may exceed the private gains if there are spillovers, i.e. students' education may cause positive benefits to society which the students do not take into account. The evidence on the presence of positive spillovers is however mixed, so we do not take this into account.

Consider now the effects on each of the three components of total welfare when a hypothetical social planner with perfect information would eliminate one product, i.e. one program at one institution.

First, such a program cut generally results in a reduced surplus to consumers, i.e. the students. They face less choice so that some students have to substitute to their next best alternative. This effect will especially be strong if students do not find good substitution possibilities for the dropped study program. In higher education substitution may occur in two directions: students may substitute to another program at the same institution or they may decide to pursue the same program but at another

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[8] For the large economic literature on optimal product diversity and comparisons with free entry or monopoly, see for example Spence (1976), Dixit and Stiglitz (1977), and Mankiw and Whinston (1986).

institution [9]. Hence, a program cut at a certain institution is bad for students if they have a strong preference for this particular program, or if they have high mobility costs so that they are not willing to travel to other campuses.

Second, eliminating a program will involve a fixed cost saving because the product no longer needs to be supplied. This fixed cost saving may for example include a reduction in the required classroom space, or a reduced teaching staff (to the extent this is independent of the number of students). The fixed cost savings may be limited if there are important economies of scope, i.e. economies from offering two or more programs at the same institution. For example, different study programs may share some of the courses, in which case classrooms and teaching staff remain needed when only one program is dropped.

Third, a program cut may result in variable cost savings if students decide to substitute to other programs that have lower variable costs. For example, closing down a medical program at a university may induce some students to substitute to a social sciences program with lower variable costs. Of course, the converse is also possible, i.e. there may be variable cost losses if students substitute to higher variable cost programs after a program cut. For example, closing down a relatively inexpensive vocational engineering program at a college may result in substitution towards a more expansive academic engineering program at a university. A program cut may therefore result in a reallocation of students to more or less expensive programs, so that the variable cost savings may be either positive or negative.

The effects of eliminating a program on total welfare are thus not clear *a priori*. It will be positive if the savings in fixed costs and variable costs (if any) outweigh the losses to students from the reduced product diversity. There is almost no empirical evidence that has attempted to estimate the students' willingness to pay for program diversity. The evidence on fixed and variable costs associated with program diversity is also limited, but there is at least some indirect evidence suggesting that scale economies are important. Cohn *et al*. (1989) and Koshal & Koshal (1999) find evidence of economies of scale and scope for US universities [10]. These findings suggest that higher education institutions can reduce their average costs by growing in size. This indirectly supports the view that reducing program diversity within an institution may raise the size of the remaining programs, and therefore imply average cost savings.

C. Too much or too little diversity?

A key question is whether the current market structure provides the correct incentives to higher education institutions to invest in program diversity. The issues are complex, but economic theory suggests that a monopolist tends to invest in too little product diversity from a total welfare perspective, whereas a market with free entry tends to generate too much diversity. The divergence from the welfare optimum stems from the fact that both a monopolist and an individual entrant do not

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[9] Students may also respond by no longer participating, but as discussed in Section 4, A, it is reasonable to assume this effect is very small.

[10] At the secondary school level, Riew (1966, using US data) and Smet & Nonneman (1998, using Flemish data) find evidence of scale economies.

have the same objective function as a social planner, implying both positive and negative externalities.

To understand the institutions' incentives to invest in program diversity, first assume that each institution behaves as a local monopolist. This means that dropping or adding programs does not result in students substituting to other universities or colleges. This assumption would be realistic to the extent that students have high mobility costs, i.e. a low willingness to travel to other institutions when a program is cut. Such a monopolist typically has an incentive to invest in too little product diversity. The economic intuition is that a monopolist correctly takes into account fixed cost and variable cost savings, but does not correctly take into account consumers' total willingness to pay. Put differently, it cannot appropriate all consumers' surplus, because it charges a uniform (and actually low) tuition fee regardless of each student's actual willingness to pay. In sum, because a monopolist institution cannot extract all consumer surplus, an essential component of total welfare, it tends to have a too low incentive to invest in product diversity.

In practice, however, the higher education institutions are not local monopolists. Students can decide not to go to the nearest institution if they find that more distant campuses offer more interesting study programs. As a result, universities and colleges may attempt to compete and steal business from other institutions by introducing additional study programs. This may ultimately lead to too much product diversity, because the business stealing effect implies only a transfer of subsidies from one institution to the other and may not mean a real contribution to total welfare.

The overall conclusion is that universities and colleges may have too little or too much incentives to invest in product diversity depending on whether the non-appropriability of consumer surplus effect or the business stealing effect dominates. The business stealing effect would dominate if student mobility costs are low so that they can easily substitute to other institutions in response to changes in program diversity.

D. Impact of the funding system reform in Flanders

Because institutions do not necessarily have the correct incentives to provide program diversity, there is room for government intervention. In Section 3, A we discussed how governments in many countries intervene by controlling quality and deciding on new programs, either through direct control or in a decentralized way through a maximum number of fundable students. Flanders had a tradition of strong direct intervention, but with its new proposed concentration index (CI) funding system, discussed in Section 3, B, it aimed to provide decentralized incentives to reduce diversity. We are interested to know (1) whether reducing diversity is actually desirable from a welfare perspective and (2) whether the decentralized CI funding system provides the right incentives to do so.

To understand the incentives created by the CI funding system, consider the effects of a program cut on the institutions' profits. Suppose first for simplicity that a program cut leads to a complete loss of students, i.e. all students from the cut program either drop out or substitute to another institution. In this case, dropping a program raises the institution's concentration index if and only if the program

Table 2 Possible profit incentives and welfare effects of unilateral program cuts

	Welfare effect	
Profit incentive	*W<0*	*W>0*
Π<0	Desirable status quo	Undesirable status quo
Π>0	Undesirable reform	Desirable reform

has a below-average size, i.e. the number of students in the concerned program is below the concentration index. Hence, the CI funding system would provide an extra incentive to drop the programs that are smaller than average. In practice, however, an institution does not loose all students of the dropped program. Some of the students may decide to go to another program within the same institution. The extent to which this happens is measured by the *diversion ratio*. The ratio is the fraction of students that goes to another program within the same institution after the institution drops a program. The diversion ratio is between zero and one. If the diversion ratio is high, the incentive to cut a program will also be high: the CI funding system may then even provide an incentive to drop programs with an above-average student size. In the extreme case where a program has a diversion ratio equal to 1, the institution does not loose any students after cutting the program, so it would even want to drop very large programs under the CI funding system.

The general conclusion is that the CI funding system provides an extra incentive to cut the smaller programs, especially if these have good substitution possibilities within the same institution. It is not however clear whether the correct financial incentives to cut programs are given in precisely those cases where this is socially desirable.

Table 2 compares the profit incentives of the CI funding system with the welfare effects and shows that there are four possibilities:

— Under “desirable status quo”, it is socially desirable not to cut product diversity and the CI funding system does not provide the incentives either.
— Under “undesirable status quo”, it would be better to cut product diversity, but the CI funding system does not provide the necessary incentives (because the program is large or has little substitution possibilities).
— Under “undesirable reform”, the CI funding system provides incentives to cut the program whereas this is not socially desirable.
— Finally, “desirable reform” means that it is good to cut product diversity and the CI funding system provides the proper incentives to do so.

5. Empirical findings

We now report on the findings of the empirical and simulation analysis by Kelchtermans and Verboven (2007). We first briefly sketch the essential aspects of the approach, and then discuss the effects of reducing diversity on demand, and on the institutions’ profits and total welfare. We focus mainly on the economic intuition without a detailed analysis of methodology and results.

A. *Methodology*

We look at the effects of reducing program diversity by considering all possible unilateral program cuts, i.e. cutting each of the 562 programs. We first simulate the demand effects from these unilateral program cuts, i.e. how students substitute to other programs. We subsequently compute the profit incentives and the various welfare effects from the unilateral program cuts.

To compute these effects we first estimated a logit model of educational choice. We had available a rich dataset from the Flemish Ministry of Education on 37,481 students, which choose one out of 562 possible alternatives (programs at different institutions). The data (summarized in Table 3) include the students' actual choices, the student characteristics (sex, nationality, years of repetition in high school, high school program, high school religious affiliation, etc.), the institution characteristics (college versus university, religious affiliation, etc.) and program characteristics (study fields). In addition, there is information on the students' and institutions' locations, enabling to compute travel distances and travel times for every student to every possible institution.

Estimation of the logit model enables us to compute the substitution effects from the hypothetical unilateral program cuts [11]. Furthermore, the logit model enables us to compute the effect on the first welfare component: gross consumer surplus or students' total willingness to pay for the various programs [12]. To compute the effect of the program cuts on the other two welfare components, variable and fixed costs, requires additional cost information. As a proxy for variable cost, we use the government's estimates that they also used to determine the cost-based variable subsidies per student (see Section 3, B). We do not have a fixed cost measure per program for each institution. However, we were able to impose reasonable upper bounds on these costs, based on the economic assumption that institutions would not offer programs if they are unprofitable. This enabled us to obtain unambiguous conclusions about profit and welfare effects for the majority of the 562 considered unilateral program cuts.

Based on this methodology we are then able to determine the demand, profit and welfare effects of reducing program diversity through unilateral program cuts. This enables us to shed light on whether the funding reform based on the concentration index was socially desirable and effective.

[11] We assume students continue to participate. As discussed in Section 4, A this assumption is based on Kelchtermans and Verboven's (2006) finding that mobility costs only have a very small effect on the participation decision (though a large effect on where and what to study). We also assume that educational quality remains constant. Given the nature of our simulations, i.e. unilateral program cuts, we consider this a reasonable assumption. Conversely, multilateral program cuts resulting in a substantially increased scale of higher education institutions may raise concerns of reduced competition. Jacobs and van der Ploeg (2005) argue this may be the case in The Netherlands where the massive increases in scale in the past twenty years have been accompanied by a dramatic increase in overhead costs and a corresponding fall in real resources per student available for teaching and research.

[12] Estimating total willingness to pay is possible because we include travel costs in our model, and convert this in a monetary measure.

Table 3 Summary statistics of 2001 eligible pupils

	All students	*College*	*University*
Demographic			
male	0.45	0.45	0.45
foreign	0.01	0.01	0.01
catholic high school	0.78	0.79	0.76
Ability			
years of repetition	0.36	0.46	0.16
	(0.95)	(0.99)	(0.83)
general high school	0.60	0.44	0.94
classical languages	0.14	0.05	0.33
modern languages	0.24	0.22	0.27
economics	0.19	0.19	0.17
sciences	0.20	0.11	0.40
mathematics	0.30	0.15	0.60
technical high school	0.33	0.47	0.04
'product'-focused	0.12	0.17	0.02
Mobility			
Distance (kms) by road to campus	34.71	30.96	42.38
	(28.17)	(25.65)	(31.37)
Time (mins) by road to campus	30.74	28.33	35.67
	(17.33)	(16.2)	(18.47)
Travel cost to campus (x10,000€)	0.38	0.35	0.46
	(0.28)	(0.25)	(0.31)
Number of observations	37,481	25,182	12,299

Standard errors for the continuous variables are in parentheses. Demographic and ability data are based on the dataset from the Flemish Ministry of Education; mobility statistics are based on own calculations using postal code information.

B. Demand effects of reducing diversity

Before looking at the demand effects of reducing program diversity, we review some of the empirical findings from estimating the logit model on our data set. The key finding is the ambiguous role of travel costs. Students tend to be quite mobile with respect to their decision whether to participate. Students living relatively far from any campus are not deterred from entering higher education. Stated differently, total demand for higher education is very inelastic with respect to travel costs.

However, students are very immobile with respect to their decision where and what to study. They often tend to choose the most nearby institution, regardless of the programs offered at that institution. This student immobility may be due to two broad reasons. First, students may perceive programs from different universities as close substitutes so that it is not worthwhile to travel further (as emphasized by Kelchtermans and Verboven (2006) based on their nested logit model results). The perceived substitutability partly follows from the large duplication of program supply (the same program being offered at multiple campuses). It may also follow from the fact that we only considered first-year undergraduate education programs, where there is naturally more homogeneity across institutions and reputational differs are less important. See also Aghion *et al.* (2007) who point at the limited reputation-based competition in most European systems of higher education [13]. Second, it is possible that students are intrinsically immobile, i.e. have high monetary or nonmonetary travel costs. Monetary travel costs may be particularly high for our sample of undergraduate students, or because of socio-economic characteristics (as proxied by secondary school variables). Regarding nonmonetary travel costs, students in Flanders may have comparatively strong ties with their social networks at home. Because the Flemish higher education area is small, students typically tend to maintain active relations with family and friends at their home location and this may induce them to choose their higher education institution while anticipating frequent weekend trips back home. This may contrast with larger countries where students know that due to large distances any schooling decision rules out frequent home visits and accordingly attach lesser importance to distance, implying higher student mobility. In sum, the observed student immobility is a relative phenomenon: it may be either due to close substitutability of programs or due to intrinsic student travel costs.

To gain further intuition on how students value current program diversity, one may use the logit model estimates to calculate the students' willingness to pay for certain study option characteristics [14]. For example, pupils who previously attended a catholic high school have an additional willingness to pay of €2,500 for attending a catholic higher education institution. Similarly, pupils who took a strong high school education (the "general" type, with classical languages) are willing to pay an additional €3,035 to attend an academic program at university instead of a short vocational program at a college (compared to pupils who took a "professional" type high school education). As a final example, pupils without repetitions during high school are willing to pay an additional €1,534 to attend an academic engineering program instead of a short vocational college program (compared to pupils who had to repeat one year in high school).

These examples indicate that removing a study program may imply big consumer surplus losses. This does not say much however about the likely substitution effects of a program cut. This will depend on the availability of close substitutes at the given campus, and on the availability of duplicate programs at other campuses (as described in Table 1).

To summarize the demand effects of reducing program diversity, the concept of the diversion ratio is very informative. Table 4 presents two kinds of diversion ratios. Diversion ratio 1 is the fraction of students that goes to another institution to attend the same field of study. Diversion ratio 2 is the measure introduced in Section 4, D,

[13] It is sometimes argued that student mobility is larger in a country such as the U.S. However, this belief appears to be based on the casual observation that students travel long distance to top universities. For lower ranked universities and colleges mobility also tends to be lower, see in particular Long (2004) for an empirical analysis of the role of distance in educational choices in the U.S.

[14] This is done by dividing the estimated valuation parameters of the study option characteristics by the travel cost parameter (expressed in Euro). We refer to Kelchtermans & Verboven (2006) for details.

Table 4 Diversion ratios resulting from unilateral study field cuts

Study field	*Colleges*		*Universities*	
	Diversion ratio 1	*Diversion ratio 2*	*Diversion ratio 1*	*Diversion ratio 2*
Architecture	0.04	0.11	0.03	0.36
Engineering	0.39	0.11	0.22	0.31
Science	n/a	n/a	0.07	0.22
Business & Economics	0.30	0.15	0.27	0.19
Education	0.22	0.15	0.10	0.30
Society	0.16	0.17	0.15	0.18
Medicine & Paramedicine	0.08	0.18	0.08	0.27
Bio-engineering	0.06	0.18	0.08	0.27
Languages	0.12	0.08	0.14	0.23
Cultural studies	0.16	0.11	0.08	0.20
Total	0.21	0.14	0.13	0.24

The diversion ratios are computed for a unilateral cut of a study field by a single institution, based on the parameter estimates of the logit model. The results reported here are averages across institutions within a given field.
Diversion ratio 1 = average % of students choosing the same study field at another institution
Diversion ratio 2 = average % of students choosing the same institution but another study field

i.e. the fraction of students substituting to another program within the same institution after a program cut. Both measures are of interest and capture the two dimensions of student choice. The first says how close substitutes other institutions are for taking the same program. The second says how close substitutes other programs are within the same institution. We report the diversion ratios from unilateral *field* cuts per institution, instead of unilateral *program* cuts reports [15].

Table 4 shows that college students are on average more loyal to their initially chosen study field than university students: the average of diversion ratio 1 across fields is 21 % for colleges, versus 13 % for universities). This may be explained by the broader supply of college programs across the region of Flanders, so that college students are more likely to find a nearby substitute campus than university students who face the elimination of their original field choice. There are important differences between study fields. For example, on average only 6 % of college students and 8 % of university students in bio-engineering stick to this study field when confronted with a cut of this field. In contrast, up to 30 % of college students and 27 % of university students in business and economics substitute to another institution to be able to stay in the same field after the field is dropped at their institution.

Diversion ratio 2 shows that university students are on average more loyal to their initially chosen institution than college students (average across fields of 24 % versus 14 %, diversion ratio 2 in the Table). Universities are thus able to retain a larger share of the affected students after cutting a study field, thanks to their broader

[15] This captures the content dimension more clearly. In the profit and welfare analysis below we look however at unilateral *program* cuts, as this was the main interest of the Flemish government.

Table 5 Actual profit incentives and welfare effects of unilateral program cuts

	Welfare effect		
Profit incentive	*Negative*	*Positive*	*Total*
Negative	37.0 %	0.3 %	37.3 %
	(desirable status quo)	(undesirable status quo)	
Positive	53.7 %	9.0 %	62.7 %
	(undesirable reform)	(desirable reform)	
Total	90.7 %	9.3 %	100.0 %

Percentages of program cuts for which it was possible to derive unambiguous conclusions on both profit and welfare effects.

supply and less competition (fewer universities across the region). Again, there is substantial heterogeneity between study fields.

In sum, the relatively low diversion ratios in Table 4 show that there is some loyalty to institutions and fields, but students substitute quite substantially to other institutions and fields.

C. Profit incentives and welfare effects of reducing diversity

Now consider the profit and welfare effects from reducing diversity through unilateral program cuts. Recall that Table 2 classified the effects of program cuts into four possible cases: desirable status quo, undesirable status quo, desirable reform and undesirable reform. Table 5 applies this classification. Using the fixed cost bounds approach mentioned above, we are able to unambiguously classify 65.4 % of all 562 cases. For the remaining part of supply, we cannot draw an unambiguous conclusion without more precise fixed cost information. We therefore focus only on the cases for which we can draw unambiguous conclusions.

We summarize here the main findings and deal with the welfare results first, as reported in the columns of Table 5. This shows that it is socially undesirable to cut a program at an institution in 90.7 % of the cases [16]. Only in 9.3 % of the cases it would be socially desirable to cut these programs. This is a remarkable result in the light of the common concerns by policy makers in Flanders with the diversity and duplication of program supply. It is driven by the low student mobility and the corresponding large willingness to pay for a given study program at a given institution. Stated differently, the large consumer surplus losses from the program cuts are typically not compensated by a sufficient amount of fixed and variable cost savings.

Next consider the profit effects of the CI funding system, reported in the rows of Table 5. In the majority of the cases (62.7 %) the CI funding system gives a positive profit incentive to cut programs. This contrasts with our earlier finding that it is usually not socially desirable to reduce diversity. Considering the four individual cells we find the following:

[16] Note that this classification is relative to the number of programs we were able to unambiguously classify (368 programs out of a total of 562 programs). As discussed in Section 5, A, we made an assumption on the upper bound of programs' fixed costs which allows us to evaluate the welfare and profit effects for the majority of study programs. Details are provided in Kelchtermans & Verboven (2007).

- We can classify 37 % of current higher education supply as desirable status quo cases, i.e. the CI funding system correctly does not give an incentive to cut programs.
- However, we can also classify 53.7 % of current supply as undesirable reform cases, where the system does give the wrong profit incentive to cut the program.
- Furthermore, we can classify a negligible fraction of 0.3 % as undesirable status quo, i.e. where cutting diversity would be desirable but the CI funding system fails to provide the incentives to do so.
- Finally, 9 % of the cases are desirable reform, where the CI funding system provides the proper incentives to cut supply.

We can draw two policy conclusions from this discussion. First, the high program diversity and the associated duplication of fixed costs across campuses is economically justified because of the low student mobility. In other words, the intuition that there is too much diversity in Flemish higher education is based on a duplication of fixed costs argument, and it ignores that students actually put a high value on this duplication. Second, policies such as the CI funding system aiming to provide decentralized incentives to reduce product diversity may easily be ineffective. The decentralized policy would have been fully effective if it had led to either desirable status quo or desirable reform (upper right or lower left cells of Table 5). In practice, this is only true for the minority of cases (37 %+9 %). In the majority of cases policy would have lead to undesirable reform by cutting diversity where this is not wanted.

6. General conclusion

We have discussed how European countries with a public system of higher education are facing increased financial challenges and how they differ in their approaches to meet those challenges. Some countries, notably the UK, have made a clear choice towards the private model by (drastically) raising private contributions. Most other countries seem reluctant to make such choices and seek other solutions to increase the efficiency of their higher education systems while keeping them essentially public. Common trends include more performance orientation as well as decentralized decision making.

One particular policy domain that is bound to attract more attention from policy makers given the pressure on public budgets, is the regulation of program supply and diversity. Governments are necessarily involved in controlling program supply, either through direct control (as in Flanders and the Netherlands) or through decentralized mechanisms (as in Scotland and Australia). Cross-country evidence suggests that program diversity is large, especially in Flanders, the region of our study. Nevertheless, despite the policy importance very little is known about the optimal degree of program diversity in higher education and even less on how policy can achieve it.

Our analysis shows that reducing supply as a way to cut costs is no magical solution. Although it may yield some fixed costs savings, i.e. efficiencies in the sense of less duplication, these are typically more than outweighed by other major inefficiencies, i.e. consumer surplus losses. Thus our analysis shows the importance of including the demand side effects, a perspective that is typically omitted from the analysis of diversity in higher education. Furthermore, we found that decentralized financial mechanisms carry a substantial risk of being ineffective, in the sense of promoting reductions in program diversity when this is undesirable from a total welfare perspective [17]. Hence, if one would want to take the route of optimizing supply diversity, a well-informed regulatory approach may be preferable unless sufficiently effective decentralized financial incentive schemes can be installed. While there is little doubt that institutions would respond to financial incentives, it is far from certain their decisions would be effective beyond a narrow definition of efficiency. In the absence of full-blown market-oriented approaches to organize higher education, it is therefore important not to make public funding mechanisms overly simplistic.

References

AGHION P., M. DEWATRIPONT, C. HOXBY, A. MAS-COLELL and A. SAPIR (2007), "Why Reform Europe's Universities?", Bruegel Policy Brief 2007/4 (see *supra*, in this volume).

BAGÜES M., M. SYLOS LABINI & N. ZINOVYEVA (2007), "Differential Grading Standards and University Funding: Evidence from Italy", *CESIfo Economic Studies*, forthcoming.

BARR N. (2004), "Higher education funding", *Oxford Review of Economic Policy*, 20(2), pp. 264-283.

BEN-DAVID J. (1972), *American higher education: directions old and new*, McGraw-Hill, New York.

BIRNBAUM R. (1983), *Maintaining diversity in higher education*, Jossey-Bass, San Francisco.

COHN E., S. L.W. RHINE & M. C. SANTOS (1989), "Institutions of Higher-Education as Multi-Product Firms – Economies of Scale and Scope", *Review of Economics and Statistics*, 71 (2), pp. 284-290.

DILL D.D., P. TEIXEIRA (2000), "Program diversity in higher education: an economic perspective", *Higher Education Policy*, 13(1), pp. 99-117.

DIXIT A. K. & J. E. STIGLITZ (1977), "Monopolistic competition and optimum product diversity", *American Economic Review*, 67(3), pp. 297-308.

HUISMAN J., E. BEERKENS & L. GOEDGEBUURE (2003), Regulating the programme supply in higher education. A comparative analysis, Ministerie van Onderwijs, Cultuur en Wetenschap, Den Haag.

HUISMAN J., F. KAISER & H. VOSSENSTEYN (2000), "Floating Foundations of Higher Education Policy", *Higher Education Quarterly*, 54(3), pp. 217-238.

HUISMAN J. & I. JENNISKENS (1994), "Comparing governmental influence on curriculum innovations: An analysis of Denmark, Germany and The Netherlands" In: *Comparative policy studies in higher education*, Lemma, Utrecht, pp. 249-272.

HUISMAN J. & C. C. MORPHEW (1998), "Centralization and Diversity: Evaluating the Effects of Governmental Policies in U.S.A. and Dutch Higher Education", *Higher Education Policy*, 11(4), pp. 3-13.

HUISMAN J., L. MEEK & F. WOOD (2007), "Institutional Diversity in Higher Education: a Cross-National and Longitudinal Analysis", *Higher Education Quarterly*, 61(4), pp. 563-577.

JACOBS B. & F. VAN DER PLOEG (2005), *Guide to Reform of Higher Education: A European Perspective*, CEPR Discussion Paper 5327.

JENNISKENS I. (1997), *Governmental steering and curriculum innovations: a comparative study of the relation between governmental steering instruments and innovations in higher education curricula*, Lemma, Utrecht.

JONGBLOED B. & J. KOELMAN (2000), Vouchers for higher education? A survey of the literature Commissioned by the Hong Kong University Grants Committee, Centre for Higher Education Policy Studies, Report nr C0BJ308.

[17] Although the incentive for reducing supply diversity that we analyzed in this paper (the concentration index) was eventually dropped from the final funding system proposal, the government reaffirmed its position that "current higher education supply is too fragmented" (Vlaamse Regering, 2007).

Kelchtermans S. & F. Verboven (2006), Participation and Schooling in a Public System of Higher Education, KU Leuven CES DP06.11 and CEPR DP5690.

Kelchtermans S. & F. Verboven (2007), Reducing product diversity in higher education, KU Leuven CES DP07.26 and CEPR DP6508.

Koshal R.K., M. Koshal (1999), "Economies of scale and scope in higher education: a case of comprehensive universities", *Economics of Education Review*, 18, pp. 269-277.

Long B.T. (2004), "How have college decisions changed over time? An application of the conditional logistic choice model", *Journal of Econometrics*, 121(1-2), pp. 271-296.

Mankiw N.G. & M.D. Whinston (1986), "Free entry and social inefficiency", *Rand Journal of Economics*, 17, pp. 48-58.

Riew J. (1966), "Economies of scale in high school operation", *Review of Economics and Statistics*, 48, pp. 280-287.

Smet M., W. Nonneman (1998), "Economies of scale and scope in Flemish secondary schools", *Applied Economics*, 30(9), pp. 1251-1258.

Spence M. (1976), "Product differentiation and welfare", *American Economic Review*, 66(2), pp. 407-414.

Trow M. (1972), "The expansion and transformation in higher education", *International Review of Education*, 18(1), pp. 61-84.

Vandenbroucke F. (2005), De financiering van het hoger onderwijs. Voorstel aan de werkgroep financiering, Conceptnota v4, 10-10-2005. Vlaams Ministerie van Onderwijs.

Vlaamse Regering (2007), Voorontwerp van decreet financiering hoger onderwijs. Memorie van toelichting. From http://www.ond.vlaanderen.be/ hogeronderwijs/ beleid/ Financiering/default.htm.

The timing of education

Thomas Gall, Patrick Legros and Andrew Newman [1]

Summary

We study an assignment-with-investment model to highlight a tradeoff between investment in human capital before (ex-ante system) and after (ex-post system) matching on the labor market. The ex-post system is better at coordinating investment within firms while the ex-ante system is better at reducing mismatches. We further show that the ability to transfer surplus within firms affects mismatches and the relative performance of the two systems. At high degrees of transferability, they are equivalent. But when transferability is very low, the ex-post system outperforms the ex-ante system, while with moderate transferability the reverse is true.

1. Introduction

For most people, education is the most significant investment they will make in their lifetimes. But the fruits of an education don't depend only on the individual making the investment: rather, they are typically jointly determined by the educations of other individuals (co-workers, firm managers), often unseen and unknown until long after the investment is made: thus sorting in the labor market is a crucial determinant of the private as well as social returns to an individual's educational investment. The efficiency of this sorting process has implications for educational policy, which has been the subject of renewed focus in the face of increased global competition.

The private returns that influence the investment decision will be determined in part by how easily the social returns can be shared within the organization in which one produces. In many situations, those returns can be shared only imperfectly: incentive problems, liquidity constraints, and "behavioral" considerations limit the flexibility of organizations to divide the pie without affecting its size. There are also

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reasons to believe that this sort of flexibility is decreasing, or at least changing, as the world economy becomes more integrated: agency problems associated with outsourcing or the dissolution of implicit contracts are examples of reduced flexibility in sharing that can arise from globalization[2].

Several literatures have studied from different points of view how imperfections within firms affect returns to investments and therefore the levels of investments that are made (Grossman and Hart, 1986; Acemoglu and Pischke, 1999). As Legros and Newman (1996, 2002, 2004a) have shown, imperfections within firms are also potential sources of *mismatche*s on the labor market. In particular, a change in the transferability of surplus within firms may modify the way agents sort themselves into firms, and, as we show here, this also affects their incentives to invest[3].

The distortion brought by mismatches on the labor market is potentially a function of *when* agents invest in education, timing that is often influenced by structural conditions and also by educational policy[4]. There appears to be considerable heterogeneity across countries in the timing of education. OECD data[5] show that the age at which tertiary education is acquired varies a lot across countries. Data points in Figure 1 are the 20-50-80 quantiles for different OECD countries. For instance, in France, 80 % of the individuals acquire tertiary education before they are 20 while for Switzerland only 20 % are less than 20 (and 80 % are less than 29 or 40 depending on the country).

This suggests that in the some countries tertiary education is achieved after having entered the labor market while in others it is achieved beforehand. The data in Figure 2 support this interpretation: it presents the conditional probabilities that an individual is working given that she is going through tertiary education, by age bracket. For the 15-19 bracket, this probability is less than 7 % for France, 30 % for the US and 50 % for Switzerland.

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[2] See for instance Kranton (1996), McLaren-Newman (2002), Legros-Newman (2004b).

[3] This distinguishes the approach in this paper from previous work by Cole, Mailath and Postlewaite (2001) and Peter and Siow (2002). The first study matching equilibria under the assumption of perfect transferability, the second under the assumption of strict non-transferability. Both consider ex-ante investments.

[4] Education policies, whether in the form of direct financing of schools, subsidies to special programs, grants at low interest rates to students, mandatory schooling, minimum standards, affect the incentives of agents to invest in education and also the time at which they acquire education. Firms can also coordinate or even finance the investment in education by their workers, either by executive education, on-the-job training, or direct subsidies for tertiary education.

[5] Figure 1 uses table C2.1 and Figure 2 uses table C4.1 from OECD (2003).

Figure 1 Age per percentile (20-50-80)

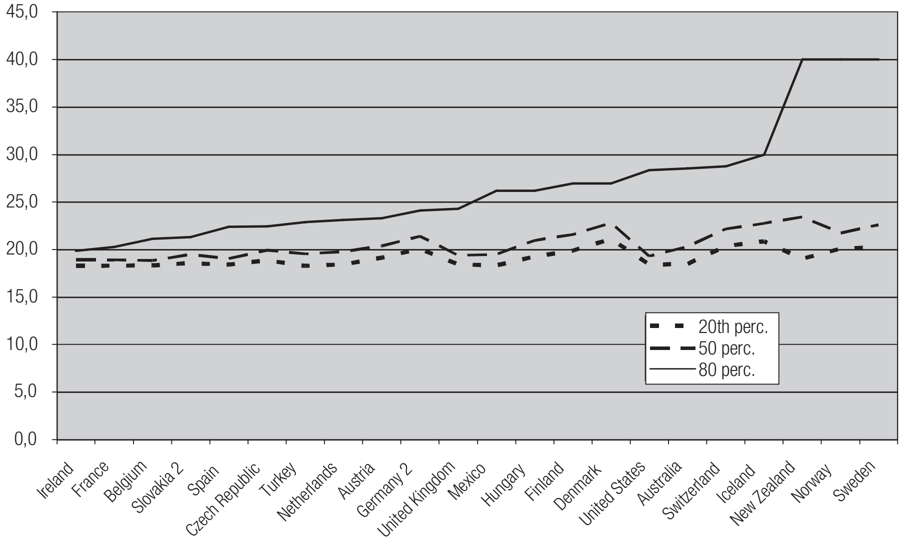
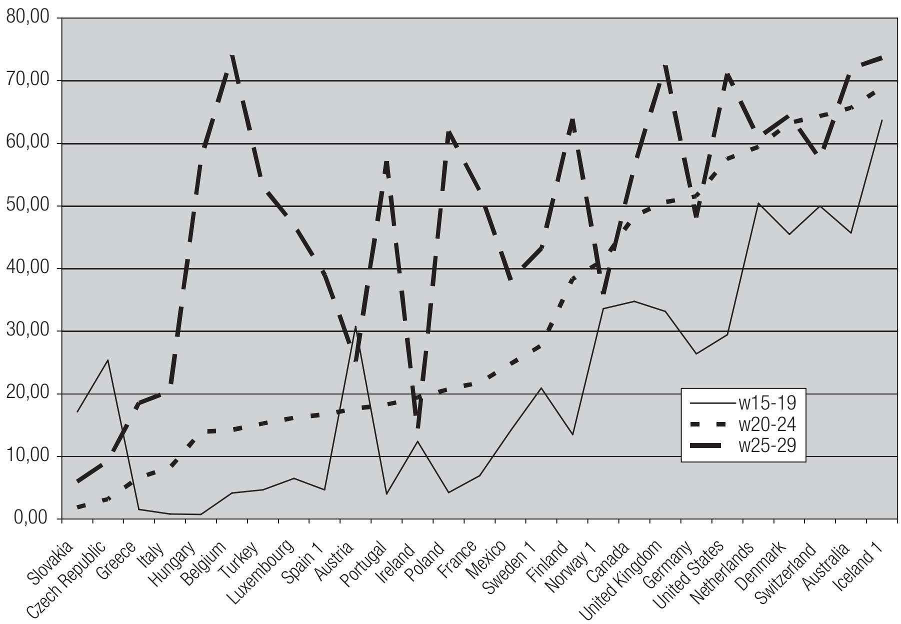


Figure 2 Conditional proba of working if in education



Educational systems play a role in influencing this timing. For instance in France most students enter *grandes écoles* just after high school and spend one or two years preparing for an entrance competition; this also applies to some of the best French business schools. By contrast in the US, business schools tend to value labor market experience among applicants[6]. Our main point in this note and in our companion paper is that the evaluation of features of educational systems, such as the timing of investments, cannot be done without considering the flexibility of firms to distribute surplus that is indirectly produced by the educational system. Insofar as both firm flexibility and educational policy are under pressure from the forces of globalization, these issues are linked not just theoretically but practically as well.

2. Model

The economy is populated by a continuum of agents. Only half of the population (the skilled) can acquire education and their cost of doing so is c, the other half of the population is composed of unskilled agents [7]. Upon investing in education agents become educated (E), otherwise they are not educated (N). All characteristics are observable. The parametric assumptions on agents' education acquisition cost are

$$c \in (1,1.5) \tag{1}$$

A *firm* consists of two agents jointly producing output. Total surplus in a firm is a function of whether agents are educated or not, $y(E,E)=8$; $y(E,N)=7$; $y(N,N)=4$.

Note that y satisfies decreasing differences. It follows from (1) that total welfare is maximum when firms consist of a skilled agent who invests in education and an unskilled agent who does not invest in education. Total welfare is then $W^{FB}=\frac{1}{2}(7-c)$.

We assume now a simple form of imperfection within firms: if output is y, then the share of an agent must lie in the interval $[(y/2)-b,(y/2)+b]$.

In other words, starting from equal sharing an agent is able to transfer at most b to the other agent [8]. This non-transferability will prevent efficient coordination on educational choices *and* on firm formation: as we will see sometimes educational choices are consistent with the first best – all skilled invest – but firm composition is not first best; at other times, firm composition is the right one – skilled and unskilled agents together – but the educational choices are not first best.

Agents can invest in education either before or after the labor market opens. Date 0 is the ex-ante stage, stage 1 is the labor market clearing, stage 2 is the ex-post stage. There is no possibility for an agent at stage 0 to sign a contract with a firm. On

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[6] Of course, the timing of education is not just due to the design of the educational system: other reasons may have to do with financial constraints, or varying opportunity costs over the business cycle.

[7] Admitting asymmetric distributions of low cost and high cost agents changes our analysis only marginally. Types' payoffs are determined uniquely by relative scarcity as the shorter market side gets all the surplus. The reader is referred to our paper Gall *et al*. (2005) for a discussion.

[8] A model of moral hazard in teams with limited liability can lead to such a constraint on shares. Wage rigidity, risk aversion, imperfect insurance or "behavioral" considerations will also lead to non-transferabilities in firms.

the *labor market* agents match in firms of size 2. Competition takes the form of wage contracts, contingent on characteristics of agents and possibly on future investment in education.

We will consider two situations:

— (Ex-ante) when all education must be acquired before the labor market opens (e.g., mandatory education). Since agents have already invested and because the costs are sunk and do not affect future production, contracts will be wage contracts. Matching will take the form of pairs (E, E), (E, N) or (N, N).
— (Ex-post) when all education must be acquired after the labor market opens, when agents are already in firms (e.g., on the job training, continuing education). Matching in the labor market at stage 1 is based on whether agents are skilled or not. Contracts define a wage structure that can be made contingent on output as well as on whether the agent has acquired education.

This ignores the possibility that agents choose when they want to acquire education. The general analysis is made in Gall, Legros and Newman (2005).

We therefore highlight two differences between the ex-ante and ex-post regimes. First, competition on the labor market is on the basis of educational achievement in the first case and cost of acquiring education in the second case. Second, educational choices are coordinated by the market in the ex-ante system while they are coordinated within a firm in the ex-post system. In the ex-ante regime, education serves as a "ticket" to get the surplus available in firms. By contrast in the ex-post regime, agents will coordinate efficiently on educational choices *given* the constraint on surpluses that the labor market imposes. As we will show, it follows that the role of non-transferabilities within firms has a different effect on educational choices and sorting in the two systems.

A. *Ex-ante*

In the ex-ante regime, an educated will be induced to form a firm with a non-educated agent only if the wage offered is greater than 4, the equal treatment payoff an educated agent can obtain by belonging to a (E, E) firm. Since the maximum wage an educated can obtain in a (E, N) firm is $3.5 + b$, it is necessary that $b \geq 1/2$. If $b \geq 1/2$, the equilibrium is the same as in the case $b = 0$ and agents segregate: skilled invest and form (E, E) firms while unskilled are in (N, N) firms.

If $b > 1/2$, competition in the labor market precludes having (E, E) firms, since unskilled non-educated agents can transfer $t \in (\frac{1}{2}, b)$ in order to attract E agents into (E, N) firms. In equilibrium, sorting must be stable and educational choices must be efficient. For stability, non educated agents must not prefer being in a (N, N) firm, that is their wage in a (E, N) firm must be large enough: $3.5 - t \geq 2$,or $t \leq 1.5$. Therefore, transfers from N to E must be $t \in [0.5, \min\{b, 1.5\}]$. For educational choices, consider the skilled agents. If $t = 1/2$, the wage of non-educated agents in a (E, N) firm is 3 which is also their total surplus (since they do not invest), the surplus of an educated agent is their wage of 4 minus the cost of education c and since $4 - c < 3$, a skilled agent would prefer not to acquire education. In order to align incentives, the wage of 3 of a non-educated in a (E, N) firm must be obtained with a probability less than one. This will happen when there is excess supply of non-educated, that is when some skilled agents do not invest in education.

Let α be the measure of skilled agents who invest; $\alpha\,[0.5$ and $\alpha/(1-\alpha)$ is the probability that a non-educated agent forms a firm with an educated agent. The expected wage of a non-educated agent is $\omega(\alpha)=(\alpha(3.5-t)+(1-2\alpha)2)/(1-\alpha)$. Therefore skilled agents prefer weakly to acquire education if and only if $3.5+t-c\geq\omega(\alpha)$, that is

$$\alpha \leq \alpha(t) \equiv \frac{1.5+t-c}{3-c} \tag{2}$$

The bound in (2) is lower than the total measure of skilled agents (0.5) only if the transfer is $t\leq c/2$. Hence when $b\leq c/2$, only a measure $\alpha(b)<0.5$ of skilled agents invest, and there are $\alpha(b)$ firms (E,N) and a measure $0.5-\alpha(b)$ of (N,N) firms forming at the labor market stage.

Proposition 1 *In the case of ex-ante education, a market equilibrium is described by a measure $\alpha(b)$ of skilled agents acquiring education, a transfer t from N to E, and the set of firms. The set of market equilibria is the following:*

— *For* low transferability ($b<1/2$), $\alpha(b)=1/2$, *there are equal measures of (E, E) and (N, N) firms, $t=0$: there is efficient investment in aggregate, but mismatching implies overinvestment within (E, E) firms and aggregate underproduction.*

— *For* moderate transferability *($b\in(0.5,\ c/2)$)*, $\alpha(b)=(1.5+b-c)/(3-c)<1/2$, *there are $\alpha(b)(E,N)$ firms and $\frac{1}{2}-\alpha(b)$* of (N,N) *firms; within (E,N) firms educated agents receive an additional transfer $t=b$: there is aggregate underinvestment and underproduction.*

— *For* high transferability ($b\geq c/2$), $\alpha(b)=1/2$, *all firms are (E,N) and* $t\in[c/2,(b,1.5)]$: *equilibrium is first-best efficient.*

Aggregate welfare is increasing in the degree of transferability b [9].

B. Ex-post

By the equal treatment property of the labor market equilibrium, agents with the same cost of acquiring education must be treated symmetrically. In a firm consisting of skilled agents, the maximum equal treatment surplus is attained when each agent invests with equal probability while the other does not invest. This can be implemented via a correlation device with values 0 and 1: when the value is 0, the first agent is asked to invest and the second does not invest and when the value is 1, the roles are reversed. Since $3.5-c>2$, the agent who is asked to invest will do so, and since $4-c<3.5$, the agent who is asked not to invest will also be obedient. Hence, the best equal treatment surplus for skilled agents is $\underline{\upsilon}_s=(7-c)/2$ while for unskilled, the best equal treatment payoff is $\underline{\upsilon}_u=2$. These surpluses are lower bounds on surpluses for skilled and unskilled agents for any value of *b*.

9 For $b=0.5$, there are two possible equilibria, corresponding to the low- and moderate transferability equilibria described in the proposition.

Consider now a firm consisting of a skilled agent and unskilled agent. A contract specifies the wage $\omega(y)$ to the skilled agent and the probability β with which this agent is expected to invest in education. For a given b, we have $\omega(y) \in [(y/2)-b, (y/2)+b]$. It is immediate that incentive compatible contracts (β, ω) satisfy

$$\beta = 1 \text{ as } \omega(7) - \omega(4) > c \tag{3}$$

$$\beta \in [0, 1] \text{ as } \omega(7) - \omega(4) = c.$$

The expected surplus of a skilled and an unskilled agents are respectively $\underline{\upsilon}_s = \beta(\omega(7)-c) + (1-\beta)\omega(4)$ and $\underline{\upsilon}_u = \beta(7-\omega(7)) + (1-\beta)\ (4-\omega(4))$. Such a firm will arise only if $\underline{\upsilon}_i \geq \underline{\upsilon}_i$.This leads to the constraints

$$\beta(\omega(7)-c) + (1-\beta)\omega(4) \geq (7-c)/2 \tag{4}$$

$$\beta(7-\omega(7)) + (1-\beta)\ (4-\omega(4)) \geq 2 \tag{5}$$

From (4), we can have $\beta = 1$ only if $\omega(7) - c \geq (7-c)/2$, or, since $\omega(7) \leq 3.5 + b$, when $b \geq c/2$. As $b = c/2$, skilled agents get the equilibrium surplus $\underline{\upsilon}_s$ while unskilled agents get a surplus of $\underline{\upsilon}_s > \underline{\upsilon}_u$. As b increases, the Pareto optimal contracts specify $\beta = 1$ and $t \in [c/2, \min(b, 1.5)]$. When $b < c/2$, we cannot have $\beta = 1$. By (3) we have $\beta \in (0,1)$ only if $c = \omega(7) - \omega(4)$, but then, the surplus of a skilled agent is equal to $\omega(4)$; now from (4) and $\omega(4) \leq 2 + b$, we need $b \geq (3-c)/2$ which is impossible when $b < c/2$ since it would imply that $c/2 > (3-c)/2$, or $c > 3/2$ which contradicts (1). Hence when $b < c/2$, agents segregate.

Proposition 2 *In the case of ex-post education,*

- *For* low to moderate transferability ($b < c/2$)*, agents segregate. In firms consisting of skilled agents, the agents correlate on a device where each bears the cost of investment with equal probability. Investment is efficient within firms, but there is aggregate underinvestment and underproduction due to mismatch.*
- *For* high transferability *(*$b \geq c/2$*), there is a measure* 1/2 *of firms consisting of a skilled agent and an unskilled agent; the skilled agent invests with probability one and receives a transfer from the unskilled agent of* $t \in [c/2, \min(b, 1.5)]$. *The first best is achieved.*

C. Comparison

Using the two propositions, it follows that the ex-post system will lead to a higher total welfare only if b is smaller than 1/2, while the ex-ante system dominates when $b \in [1/2, c/2]$ and the two systems are equivalent when $b \geq c/2$. This comparative static result is a consequence of the role of education in each system. While the ex-post system has an advantage at coordinating educational investments *within firms*, the ex-ante system is better at aligning educational incentives with marginal returns on the labor market; this marginal return of investment is however a function of the sorting on the labor market, which can be inefficient. Hence, the ex-ante system performs best when there is "enough" transferability within firms.

When there is a low degree of transferability, both systems suffer from mismatch. To move from segregation to the more efficient regime of mixed firms would require a departure form equal sharing, which is very costly under low transferability. The ex-post system at least coordinates on education, so saves resources that are wastefully spent in the ex-ante regime.

But this greater coordination efficiency is the ex-post regime's undoing when transferability increases to moderate levels. For now the ex-ante system moves away from segregation, while the large payoff to the skilled that obtains under the ex-post system becomes a hindrance to compensating them for the extra burden of education that they must assume in mixed firms. Thus mismatch remains a problem for the ex-post regime. Ex-ante firms gain more from increased monetary transferability than ex-post firms because the latter already a form of imperfect transferability through their allocation of the investment burden.

3. Concluding remark

Many countries now view themselves as undergoing crises in education. The forgoing analysis raises the possibility that reductions in the flexibility of firms to share surplus (brought on for instance by globalization) may be part of the reason. Educational systems that resemble our ex-ante case may have worked well in the past, but may no longer be optimal if transferability has decreased.

References

Acemoglu D. and J.-S. Pischke (1999), "The Structure of Wages and Investment in General Training", *Journal of Political Economy*, 107(3), pp. 539-572.

Becker, G. S. (1973), "A Theory of Marriage: Part I", *Journal of Political Economy*, 81, pp. 813-846.

Cole H. L., G. J. Mailath and A. Postlewaite (2001), "Efficient Non-contractible Investments in Large Economies", *Journal of Economic Theory*, 101, pp. 303-373.

Gall T., P. Legros and A. Newman (2005), "Mismatches and Sequencing of Investment", mimeo, ECARES.

Grossman S. and O. Hart (1986), "The Costs and Benefits of Ownership: A Theory of Vertical and Lateral integration", *Journal of Political Economy*, 94(4), pp. 691-719.

Kranton R. (1996), "Reciprocal Exchange: A Self-Sustaining System", *American Economic Review*, pp. 830-851.

Legros P. and A. F. Newman (1996), "Wealth Effects, Distribution, and the Theory of Organization", *Journal of Economic Theory*, 70(2), pp. 312-341.

Legros P. and A. F. Newman (2002), "Monotone Matching in Perfect and Imperfect Worlds", *Review of Economic Studies*, 69(4), pp. 925-942.

Legros P. and A. F. Newman (2004a), "Beauty is a Beast, Frog is a Prince: Assortative Matching with Nontransferabilities," mimeo, revised version of CEPR DP 3462, 2002.

Legros P. and A. F. Newman (2004b), "Vertical Integration, Managerial Firms, and Consumer Welfare", mimeo.

McLaren J. E. and A. F. Newman (2002), "Globalization and Insecurity", mimeo.

OECD (2003), "Education at a glance", available at http://www.oecd.org.

Peters M. and A. Siow (2002). "Competing Pre-marital Investments", *Journal of Political Economy*, 110, pp. 592-608.

Part II

Individual higher education organizations

Multi-dimensional contracts with task-specific productivity: An application to universities

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Summary

Academics produce science and teaching which requires specific unobservable characteristics. Applying the multi-dimensional screening methodology of Armstrong and Rochet (*European Economic Review*, 1999), it is shown that universities optimally propose a menu of contracts to academics: high powered incentives for those who are productive and lower ones for other agents. In some cases, the university can write a single contract for both tasks to increase production. An academic is then expected to produce more teaching to show that she likes science, which is an argument to produce science and teaching in a single institution: universities. These results are discussed in light of economic, sociological and educational literature.

1. Introduction

Universities have two main tasks: to produce science, that is, contribute to the advancement of knowledge and teaching, that is to train students and disseminate knowledge. However, it is not clear that the same institution should do both. There is a vivid debate on the subject.

From a historical perspective, research entered universities only recently (see among others, Goldin and Katz, 1999; Hattie and Marsh, 2004). Before entering universities, research was produced under aristocratic patronage. Kings and nobility, concerned with the benefits of sponsorship (self-esteem, image, etc.), competed for the production of novelty by "their" researchers (David, 1998). According to many authors, Wilhelm von Humboldt brought research into universities during the nineteenth century (see, for example, Lenoir, 1998; Schimank and Winnes, 2000). His

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initial idea was the following: the role of the professor is to introduce students to the techniques of scientific problem solving and this should be done through research-based teaching: doing research with or in front of her students.

This practice proved to be successful, but nowadays most courses in universities, especially those aimed at undergraduates, are no longer directly in touch with recent research. Moreover, since the number of students has increased drastically, teaching tasks require more investment by professors. It is interesting that these complaints appeared just after the universities got their second mission: during the second part of the nineteenth century "the recognition dawned that the fusion of teaching and research providing the rationale for developing these institutions in fact hindered science's advance, since the bulk of resources had to go into supporting time-consuming low level training" (Lenoir, 1998).

Nowadays, the higher education institutions themselves have opposing views as can be seen when surfing their web pages. The main research universities want to build upon their recognized ability to produce science and suggest that research directly benefits the students. This leads to sentences like "Undergraduates, from the very first year, enjoy (...) research opportunities" or "research is to teaching as sin is to confession, one does not go without the other". But the teaching colleges emphasize the unique devotion of their staff to students.

Besides these actors, the question of the separation of the production of science and teaching has recently received a lot of attention by academics. A stream of papers appeared with the decision by the United Kingdom to reward research excellence. It was then decided to assess the quality of the research output of higher education institutions and to fund these institutions according to their results. This move by the United Kingdom led scientists and governing bodies to attempt to have an educated view on the pros and cons of having a single institution to produce both science and teaching.

Most papers emphasize the ex post, moral hazard problem of multitasking. In a seminal paper, Holmstrom and Milgrom (1991)[2] study contracts that reward efforts as a linear function of the observed outputs. They show that under these conditions, encouraging effort on one task generally crowds out efforts on the other tasks. In our case, this means that putting high powered incentives on research (promotions, opportunity to travel, peer esteem, etc.) reduces the attention on teaching (Dewatripont *et al.*, 2001)[3].

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[2] See also Dewatripont *et al.* (2000) for a discussion.

[3] Many observers (see Qamar uz Zaman, 2004) consider that incentives are too generous on research which leads academics to neglect teaching. Tullock (1993) states: "under present circumstances, academic salaries are determined almost entirely by research and very little by teaching, with the result that little attention is given to teaching"; and later in the same text describing the different types of professors, "one type that most of us have encountered around academic areas is the man who is deeply devoted to teaching and puts a great deal of time and energy into that activity. He normally is making significant financial sacrifice because teaching just does not pay in modern academe". The evidence is less clear however. Dearden *et al.* (2001) report that the mean weight given to research is 55 % in tenure decisions (they survey 15 medium-sized institutions in the U.S.). Euwals and Ward (2000) examine wages in 5 British universities and conclude: "perhaps surprising in this respect is the importance of teaching skills, which are revealed to have a sizeable impact on pay in our simulations".

In this paper, I deal with the ex ante selection problem. More precisely, I assume that academics have task-specific characteristics (some are more productive at teaching and/or research), which implies that some agents produce more for a given reward. Moreover, universities design contracts in which they reward good production through tenure or improved working conditions. It is argued that in some cases, it can be attractive to produce research and teaching in the same institution.

In the model, based on Armstrong and Rochet (1999), universities propose several types of contracts. Some contracts are high powered (a high reward for a high production but a sanction for low production) and are chosen by those agents who are productive. Other contracts are less linked to production and are chosen by agents who are less productive. It is argued further that the university can under some conditions, increase the production standards using the *bundling mechanism*[4]. The university brings the production of teaching and research under a single contract. When the contract is written, the university endogenizes the fact that some individuals like, for instance, research: in order to prove that they want to get a research contract, they are expected to make an extra effort on their teaching tasks.

The *bundling mechanism* formalizes an intuition put forward in the interpretation of some empirical studies. de Groot *et al*. (1991) analyze the economies of scale and scope in public and private universities. They do not find any economies of scope for joint production of teaching and research, but they find economies of scope between graduate and undergraduate instruction. They suggest that "this could be explained from the cost savings obtained by employing graduate students as teaching assistants at a relatively low price". As in our paper, it is profitable to 'bundle up' graduate studies and undergraduate instruction; to show their motivation for graduate studies, agents make an extra effort on undergraduate instruction.

The model in this paper is also useful to analyze the relation between a subsidizing government and higher education institutions. The evaluation and the funding of these institutions are discussed in the light of the *bundling mechanism*. It is argued that the *bundling mechanism* is less likely to apply in this case. Indeed, the *bundling mechanism* is most useful when types are not too positively correlated, that is, when it is not too probable that the same individual is productive for teaching *and* research. It seems that types are more correlated at the group (or university) level than at the individual researcher level. This is why the bundling mechanism is more useful at the individual researcher level.

The paper is organized as follows. First, some of the main arguments in favor and against the joint production of science and teaching are discussed. An emphasis is placed, on the one hand, on common desired characteristics that are useful to teach and do research, and on the other hand, on time scarcity. In Section 3, the main assumptions of a model are presented; it builds extensively on Armstrong and Rochet (1999) who launched the discrete-type multi-dimensional screening literature. In Section 4, the results are derived and it is shown that the university can take

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[4] The multiproduct literature calls "bundling" the practice of selling a good to a consumer not only on the basis of her preferences for this good but also depending on her type for other goods (see e.g. Avery and Hendershott, 2000).

advantage of its monopsony power to increase output by "bundling up" the tasks together. Some subsections are devoted to understand more precisely how a relatively positive correlation (linked to common teacher and researcher characteristic) or negative correlation (linked to tight time constraints) affect expected output of the university and rents of the academics. The final section concludes.

2. Technical complementarity

Before coming to the model, it may be useful to review some arguments in favor and against joint production of teaching and research. Indeed, as will become clear later on, a central issue will be whether productivity on teaching tasks is correlated with productivity on research. Regarding this issue, the scientific literature and the popular press focus mainly on two subquestions:

— Are there common "desired characteristics" to teach and do research?
— Is time scarcity a big issue?

Many papers defend opposing views concerning these questions. It is ultimately an empirical question. Unfortunately, the lack of precise empirical work leaves us without a satisfactory answer.

According to Qamar uz Zaman (2004), Coaldrake and Stedman (1999) and Neumann (1994), scientists should develop an attitude of inquiry: they should test and be critical about their findings. Moreover, they should be imaginative, work hard and be able to express their ideas clearly. These characteristics are also valuable for teachers. Besides innate abilities, being active in research might improve teaching skills and vice versa. It is suggested, for instance, that research puts the academic in the position of a learner which will lead the teacher to understand the learning experience. Teaching is then best produced by researchers who are used to deal with unsolved problems and can share their experience with their students (see Elton, 2001; Brown, 2004 and Qamar uz Zaman, 2004). Seemingly, some authors (Qamar uz Zaman, 2004; Becker and Kennedy, 2004) support the idea that being an active teacher enhances research abilities because they have to clarify their thoughts and make sure that the broad picture (in which their own findings fit) is comprehensible. It is also possible that discussions with students, questions during a class or creating examples provide avenues for new research.

On the other hand, Hare and Wyatt (1992) and Schimank and Winnes (2000) emphasize that teachers must be understood by a large proportion of their students. This is not always the case in research (as suggested by Mas-Colell, 2003, when he compares science to politics) "in contrast to the latter; in political speeches (...) it is a terrible faux pas to direct one's words to the three people that matter". Moreover, brilliant researchers might set their expectations of students' understanding at too high levels, have a poor tolerance for alternative points of view and distort the curriculum toward their own research (Qamar uz Zaman, 2004).

Besides the characteristics of the academics, another highly debated subject is the presumed negligence of successful researchers when they come to teaching. Following this idea, those academics are assumed to divide their time unequally, give an absolute priority to research and be less available to their students. The editor of the

Indiana University research magazine states this quite clearly: "Outrageous examples exist of "prima donnas" and "superstars" for whom research trumps teaching every time, leading legislators and others to decry the ruination of higher education, proclaiming students as losers in the 'research vs. teaching' fight" (Bryant, 2004).

Time scarcity is often associated with increasing returns to scale in research. Indeed, research output is strongly skewed and some authors suggest that the academics who are the most productive researchers should concentrate on that task (see among others, Tullock, 1993 or Coaldrake and Stedman, 1999). The skewed output finds its origin in the winner takes all type of contest in which scientists are engaged: the first team that finds a result is disproportionately more rewarded than the first team which can replicate a result. Being first matters a lot. Moreover, history matters: having been first in the past increases the attention of colleagues to present results. This leads to the so-called Matthews effect in science, where success attracts success (Stephan, 1996).

These two arguments are central, but there is not a one to one trade-off between teaching and research time because some of the time spent on research would not have been spent on teaching anyway. Tullock (1993) states this in a rather funny way: "It is likely that for a sizeable part of the faculty, golf is a more severe competitor to time spent preparing lessons than is research". In line with this, Colbeck (1998), who studied the time allocation of academics, reports a dialog with a professor who says that "his main strategy for achieving both classroom teaching and research goals was "working long hours"". Besides leisure and research, many other activities consume academics' time: consulting, administrative work, scientific popularization, etc.

Moreover, and this goes back to the above section, it is often not clear if time is spent on research or on teaching. Colbeck (1998) suggests that integrated research and teaching time, which he defines as "activities that accomplish teaching and research goals at the same time", represents on average 19 % of the working time of faculty members.

Theoretical arguments go in various directions for the two questions discussed above. Which effects dominate can only be discovered through empirical investigation. Unfortunately, the various empirical contributions differ in the precise question they want to answer, their databases and the methods used. Some study the group level (department, university, etc.); some study the individual level (professor). The country studied is also crucial since the higher education systems are very different. All this complicates comparisons.

An interesting branch of the empirical literature originating with Cohn *et al.* (1989) uses the methodology developed by Baumol *et al.* (1982) to analyze the economies of scale and scope in industries producing multiple goods[5]. Cohn *et al.* (1989) find economies of scope for public and private universities; "these results are particularly interesting, because they suggest that teaching and research are comple-

[5] Ray economies of scale exist if total costs increase proportionately less than output as production is expanded proportionately along a ray emanating from the origin. Product specific economies of scale exist if total costs increase proportionately less than output as the output of one product is expanded. Economies of scope measure the cost savings accruing to firms producing two or more products jointly against specializing in the production of a single output (Definitions of Dundar and Lewis, 1995).

mentary". In particular, they find a strong interaction between research and undergraduate enrollment. de Groot *et al*. (1991) do not find any economies of scope for joint production of teaching and research. However, they find economies of scope between graduate and undergraduate instruction. As emphasized in the Introduction, these findings are coherent with a *bundling mechanism* for graduate students; these students are expected to furnish an extra effort on teaching tasks. Dundar and Lewis (1995) and Koshal and Koshal (1999) study, respectively, public universities and comprehensive schools with the same methodology. They both find that producing research and teaching together is advantageous. Dundar and Lewis (1995, 1998) make a discipline specific analysis of the complementarity between graduate teaching and research. Unlike in the social sciences, they found complementarity in the physical and engineering sciences. The reason is similar to the above argument of de Groot *et al*. (1991) but this time, graduate students lower research costs instead of teaching costs: "the reason (…) is that faculty can use graduate students as research assistants" (Dundar and Lewis 1995). Concerning the overall economies of scope, Dundar and Lewis (1995) find that "the results indicate that for all the departments there appear to be economies of joint production from combining the production of teaching and research". These results are confirmed in a recent paper using new techniques by Bonaccorsi *et al*. (2006). They show that beyond a threshold quality of publication, increasing scientific quality improves educational efficiency.

Other studies aim at studying the joint production of research and teaching by individuals. Gottlieb and Keith (1997) use an international survey and find a positive correlation, but other authors, such as Noser *et al.* (1996) or Hattie and Marsh (1996) report a negative interdependence. Following Mitchell and Rebne (1995), it is not impossible that both are right. They evoke the possibility that a limited amount of teaching improves research output but, above a certain threshold, increasing teaching loads reduces research productivity. Hattie and Marsh (2004) conclude that "there is a tension between the time devoted to the two activities, *but this tension may not be translated into differential outcomes*"[6]. Besides universities, Bodenhorn (1997, 2003) shows that faculty members of liberal arts colleges publish an increased number scientific articles although these institutions focus their attention on teaching.

3. The model

The arguments reviewed until now were mainly technical, that is: "it is easier (more difficult) to produce science if one already produces teaching". In what follows, arguments are presented concerning the relation between the producer and her employer. In some cases, it turns out that joint production is efficient even in the absence of any technical advantage.

[6] Italics in the text.

A. Assumptions

1. *The utility function of the academic*

The academic maximizes her utility, which is separable in (quadratic) cost of effort and wage:

$$R_{ij} = E\left[w_{ij}\right] - \frac{1}{2}\left(c_i^s\left(s_{ij}\right)^2 + c_j^t\left(t_{ij}\right)^2\right)$$

where R_{ij} is the utility of agent ij, $E[\cdot]$ is the expected outcome, s_{ij} (t_{ij}) is the output that the agent ij produces on science (teaching), w_{ij} is the wage paid to agent ij.

There are different types of agents who differ in the marginal cost of producing teaching and science. Some have a higher marginal cost: $\frac{1}{2} = c_L^k < c_D^k = 1$ for $k = s, t$. To simplify, consider a discrete model with four types: $ij \in \{LL, LD, DL, DD\}$. These type-dependent marginal costs may have various origins. Throughout the paper, *LD* represents an agent who *likes* (*L*) science and *dislikes* (*D*) teaching. Agents who *like* a task incur a lower cost to do the piece of work[7].

The cost of effort on one task is independent of the effort furnished on the other task. Task independence should be interpreted as a neutral benchmark: time scarcity leads the cost of effort on one task to increase with the effort on the other, and technical complementarity goes the other way[8]. However, the effort an agent exerts on science (s_{ij}) or on teaching (t_{ij}) is not only a function of her type regarding this task (i for science and j for teaching). It will become central in what follows, that the effort depends on the characteristics of the agent regarding both tasks.

2. *The university system as a weighted output maximizing monopsony*

The university is a weighted output maximizing monopsony. Its objective is specified as:

$$\max \sum_{ij} \alpha_{ij}\left(E\left[p_s s_{ij} + p_t t_{ij}\right] - w_{ij}\right) \tag{1}$$

where $E[\cdot]$ is the expected outcome, s_{ij} (t_{ij}) is the output that the agent ij produces on science (teaching), w_{ij} is the wage paid to agent ij and $p_k > 0$ (for $k = s, t$) represents a "subjective" weight that the university puts on teaching and science. These weights

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[7] Although I use the terms *like* or *dislike*, one could have in mind "is efficient at producing" or "is not efficient at producing". This would fit the equations just as well. Assuming that some agents like the reward more than others would lead to a similar model (if w_{ij} is separated between science and teaching and includes the working conditions, like traveling or an improved laboratory, for instance).

[8] The conclusions derive from an optimal steering of agents' behavior and not from a "technical complementarity" of the production of science and teaching described in Section 2. One can show, and I will return to this later, that time scarcity leads the tasks to become strategic substitutes (if you choose to do one, you cannot do the other as well). This can be reinterpreted in our model as a negative correlation of types (*LD* and *DL* are more frequent). Similarly, in the presence of technical complementarity, the tasks become strategic complements (doing one increases your ability to do the other). This is similar to positively correlated types (*LL* and *DD* are more frequent).

are assumed to be given. The ex ante probability a_{ij} for an agent to have type ij is common knowledge.

The objective function of the principal deserves some comments. First, although a large majority of universities do not maximize their profit[9], it seems reasonable to assume that they maximize the difference between output and wages; a difference that they could use to subsidize other activities[10]. The word "profit" will be used for the objective of the university in what follows.

Second, many authors have suggested that universities make use of monopsony power in their relation to their employees. There are several reasons leading to this monopsony power. Academics have very specialized human capital and can mainly be employed in universities. Universities themselves are not close substitutes to one another: they are specialized in some disciplines, their quality is highly stratified, they are located in different cities, etc.[11]. Moreover, academics value the interaction with highly qualified colleagues. This implies a coordination game where academics coordinate on some universities, which have de facto a higher bargaining power[12].

Analyzing the strategic interaction between universities would go far beyond the scope of this paper. To take the outside world into account, it is assumed that the university faces academics who may leave their institution. If the academic chooses to leave her institution, she will get a utility R called outside option. For simplicity, $R = 0$ is assumed. The reservation utility is independent of the individual characteristics of the academic in this setting.

It is implicitly assumed in this paper that there is only one academic candidate for an open position in this setup. The university hires the candidate whenever the value of her output is higher than her cost (including direct costs such as wages and indirect costs in terms of increased rents to other types of candidates).

Another embedded assumption is that the output produced by an academic is assumed to be observable and the relative weights of science and teaching are given. Anecdotal evidence suggests that evaluating and comparing different sets of output leads to delicate negotiations[13].

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[9] There is an abundant literature commenting on universities as nonprofit institutions. For a discussion, see Cowen and Papenfuss (1997) or Carlton *et al.* (1995).

[10] Diamond (1993) states this quite clearly: "A nonprofit organization can make a profit in the usual sense that revenues may exceed costs. What distinguishes the nonprofit organization is that the managers, board of trustees or other 'owners' cannot distribute the profit among themselves: they must be held in reserve or else be used to increase the future expenditures of the organization".

[11] See for instance Ransom (1993), Masten (1995, 1999), Barbezat and Donihue (1998), Euwals and Ward (2000).

[12] The monopsony power of the universities is well documented. Ransom (1993) finds a negative relationship between seniority and salary of professors (controlling for productivity and individual characteristics). He argues that his findings are consistent with monopsonistic salary discriminations by universities. Barbezat and Donihue (1998) and Hallock (1995) moderate these findings. They conclude, however, that "the tenure system (…) is related to an employer's willingness to compensate seniority. If reduced faculty mobility accompanies the granting of lifetime employment, employers may gain monopsony power over tenured faculty" (Barbezat and Donihue, 1998).

[13] Committees spend a long time discussing the relative value of certain research output and teaching output. Dearden *et al.* (2001) survey 15 medium size private U.S. universities. These universities are asked how they value teaching and research. Some universities give precise weights to research and teach-

3. A symmetric situation

Let us assume a "*symmetric situation*" where half of the population *likes* research or teaching: $\alpha_{LD} + \alpha_{LL} = \alpha_{DL} + \alpha_{DD} = \alpha_{DL} + \alpha_{LL} = \alpha_{LD} + \alpha_{DD} = \frac{1}{2}$. This simplifies the equations because there is only one variable left: the correlation between types $\left(\alpha \in \left[0, \frac{1}{2}\right]\right)$ and all the other variables can be defined as:

$$\alpha_{LL} = \alpha_{DD} = \alpha$$

$$\alpha_{LD} = \alpha_{DL} = \frac{1}{2} - \alpha$$

So, an increase in α leads to an increase in the correlation of the types, i.e. the probability that an agent *likes* teaching if she *likes* research.

B. The optimal contracts

The screening literature is concerned with the design of contracts when the principal is unable to observe some characteristic of the agent that influences the production process. In our case, the university does not know if the academic *likes* teaching and research.

The university optimally offers a menu of contracts and leaves the contract choice to the academic. This menu includes different contracts specifying the rewards depending on the observed outcome. In some contracts, efforts, expected outputs and rewards (if production is satisfactory) are higher, but if production does not satisfy the standards, the reward is much lower. These contracts with high powered incentives (the reward is highly linked to the output) are chosen by the academics when they believe (knowing their type) that they are able to meet the requirements. If not, they may choose another contract where incentives are less powerful: the university expects a lower effort, a lower production and provides a lower reward. The academics choose these contracts when they are unwilling to produce the effort to create the output required in the contracts for more desired types. This is the case when their marginal cost of effort is high. A real life example would be a variable tenure track job in which the candidate has to choose the length of the tenure track: more productive agents go for a shorter time period which means a higher expected utility but also a higher expected effort.

The university uses the relation between observed outcome (or the effort) and the reward as screening device for the unobserved characteristic: if the menu of contracts is well designed, the agents choose the contract designed for them – when they *like* the task, they produce a high level of output and get high wages, when they *dislike* the task, they produce and are paid less.

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ing for awarding tenure or promotion to full professor (such as 80-20 for example), while others leave these weights open, answering for instance: "varies: teaching ranked second but very important".

In what follows, I investigate the desirability to group the tasks under one contract (i.e., one reward for a given output of research *and* teaching) or to provide two separate contracts, each one rewarding the production of a single task. I show that under certain circumstances, it is more profitable to write a single contract for research and teaching.

C. No risk

It is assumed that the university and the academics are risk neutral. It is clear from what precedes that academics are exposed to risks when they choose a contract: either they favor high requirements and a high wage when they meet the standards (but any failure is severely penalized) or they choose for insurance (easily met standards but lower wages). An academic who *likes* both tasks may choose the contract with low standards because she wants some kind of insurance. This behavior will be excluded since risk neutrality is assumed. Risk neutrality on both sides will lead to ignore expectations and write a deterministic production function where the principal infers an agent's effort from the observed output.

Assuming a deterministic production function (or risk neutrality) implies a little change in perspective. We will be less concerned in what follows by the contract (high powered incentives and low powered incentives) and more concerned by the expected production. High production should, however, be associated with high powered incentives.

The importance of risks will be briefly discussed here. First for scientific output, the relation between efforts and output is widely studied, especially regarding the risks involved (see Dasgupta and Maskin, 1987; Dasgupta and David, 1994; Stephan, 1996). The main risk for a scientist is to spend time and energy on a project without getting published. Valuable research may end up not being published for a variety of reasons. Let us single out two of them: referees and editors may not understand the value of the work or another team may have published the same results before. These risks can be reduced, for instance, by belonging to networks or by the practice of gift giving: scientists may acknowledge intellectual debt to their colleagues via citations as an insurance against bad peer review or ignorance. Concerning teaching, there are problems with the main instruments to observe teaching efforts. The literature (Becker, 1997; Becker and Watts, 1999) shows, in particular, that Students Evaluations of Teaching (SET) are polluted by grades obtained and physical, sexual and ethnical characteristics of the teacher.

However, a small part of the salary of an academic depends on explicit incentives. This means that the most important decisions relying on the observation of output can usually embody a larger set of measures, so that the relative poverty of the signal can be partially balanced by a larger number of observations. If one thinks of tenure track jobs, the principal can usually rely on several years of signals about teaching and research when she decides on how to reward an individual. This reduces the risk borne by the academic.

4. The optimal multidimensional screening contract

A. *The methodology of Armstrong and Rochet (1999)*

The methodology used in this paper was introduced by Armstrong and Rochet (1999). In order to reduce the length of the expressions in what follows, let us define:

$$\Delta(k) = \frac{1}{2}\left(1 - c_L^k\right) k^2 = \frac{k^2}{4}, \quad k = s,t \tag{2}$$

an increasing function of efforts. As emphasized earlier, a given effort k requires a higher cost when the agent *dislikes* the task. The function $\Delta(k)$ expresses this difference of costs for a given effort k. It simplifies the expressions of the incentive compatibility constraints since the cost for type LD to mimic type DD is $\Delta(t_{DD})$.

$$S_{ij}^k = p_k k_{ij} - \frac{1}{2} c_i^k \left(k_{ij}\right)^2, \quad k = s,t$$

where $c_i^k \in \left\{c_L^k = \frac{1}{2}, c_D^k = 1\right\}$ is the total surplus produced by agent ij on activity k.

The first-best effort maximizes this surplus

$$\bar{k}_D = \frac{p_k}{c_D^k} = p_k < \bar{k}_L = \frac{p_k}{c_L^k} = 2\,p_k, \quad k = s,t$$

$\bar{s}$ and $\bar{t}$ do not depend on the entire type of the agent; they depend on the type for the activity. This means that if the principal could observe the types, she would not take the second dimension into account to define the required effort levels. Using the definition of the surplus and risk neutrality, the principal's objective function (1) can be expressed as

$$\sum \alpha_{ij} \left(S_{ij}^s + S_{ij}^t - R_{ij}\right) \tag{3}$$

The principal maximizes her objective function (3) subject to the participation constraint (agents can use their outside option normalized to $R = 0$) and the incentive constraints (agents choose the contract designed for their type). The participation constraints require that $R_{ij} \geq R = 0$ for any ij. Since $\Delta(k) = \frac{k^2}{4} > 0$, the only relevant constraint is that of the lowest types $R_{DD} \geq 0$. The contract designed for the *low* types always brings a higher utility to the other types than their reservation utility.

Armstrong and Rochet (1999) distinguish mutually exclusive cases related to the binding incentive constraints. As will become clear, whether a constraint binds depends, in turn, on the correlation between types (the value of a) and on the relative weight of teaching (p_t) and science (p_s). Armstrong and Rochet distinguish the cases where only *downward* incentive constraints bind and the cases where some *upward* constraints bind. *Downward* constraints prevent an individual who *likes* one of the tasks from choosing a contract designed for someone who *dislikes* the same task.

Figure 1 summarizes the cases where only downward constraints bind[14]. Similarly, an *upward* constraint (see Figure 2) prevents an individual who *dislikes* one of the tasks from choosing a contract designed for someone who *likes* this task. Constraints that prevent an agent who *likes* one task and *dislikes* the other (*LD*) from mimicking the reverse (*DL*) are classified as upward constraints.

Armstrong and Rochet show that when only downward incentive constraints bind, (3) can be rewritten as:

$$
\begin{aligned}
&\alpha\left\{S_{DD}-R_{DD}+S_{LL}-R_{LL}\right\}+\left(\frac{1}{2}-\alpha\right)\left\{S_{LD}-R_{LD}+S_{DL}-R_{DL}\right\}= \\
&\alpha\left\{p_s s_{DD}+p_t t_{DD}-\frac{1}{2}\left(\left(s_{DD}\right)^2+\left(t_{DD}\right)^2\right)\right\} \\
&+\left(\frac{1}{2}-\alpha\right)\left\{p_s s_{DL}+p_t t_{DL}-\frac{1}{2}\left(\left(s_{DL}\right)^2+c_L^t\left(t_{DL}\right)^2\right)-\Delta\left(t_{DD}\right)\right\} \\
&+\left(\frac{1}{2}-\alpha\right)\left\{p_s s_{LD}+p_t t_{LD}-\frac{1}{2}\left(c_L^s\left(s_{LD}\right)^2+\left(t_{LD}\right)^2\right)-\Delta\left(s_{DD}\right)\right\} \\
&+\alpha\left\{p_s s_{LL}+p_t t_{LL}-\frac{1}{2}\left(c_L^s\left(s_{LL}\right)^2+c_L^t\left(t_{LL}\right)^2\right)-\begin{bmatrix}\gamma_1\left(\Delta\left(s_{DD}\right)+\Delta\left(t_{DD}\right)\right)+ \\ \gamma_2\left(\Delta\left(s_{DL}\right)+\Delta\left(t_{DD}\right)\right)+ \\ \gamma_3\left(\Delta\left(s_{DD}\right)+\Delta\left(t_{LD}\right)\right)\end{bmatrix}\right\}
\end{aligned}
$$

where the $\gamma_i \geq 0$ are similar to Lagrange multiplier associated with doted constraints in Figure 1. $\gamma_i = 0$ if the relevant constraint does not bind, and $\gamma_i > 0$ if the relevant constraint does bind.

[14] A continuous line in Figure 1 indicates that the constraint always binds. A dotted line means that, depending on the case, the incentive constraint might bind or not. The arrows show in which direction the constraints bind; that is, an arrow from *LL* to *DD* indicates the principal wants to deter *LL* from mimicking *DD*.

Figure 1 Downward Incentive Constraints

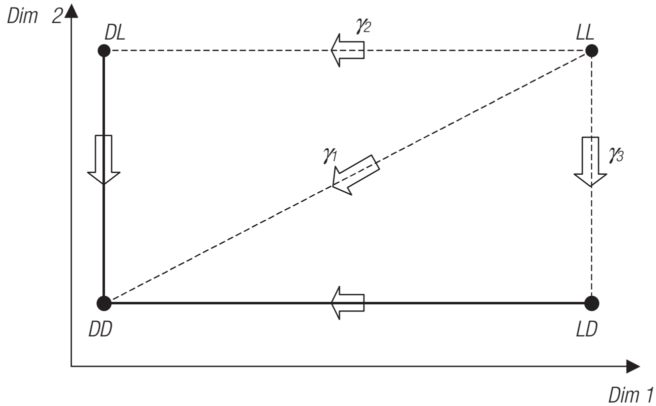
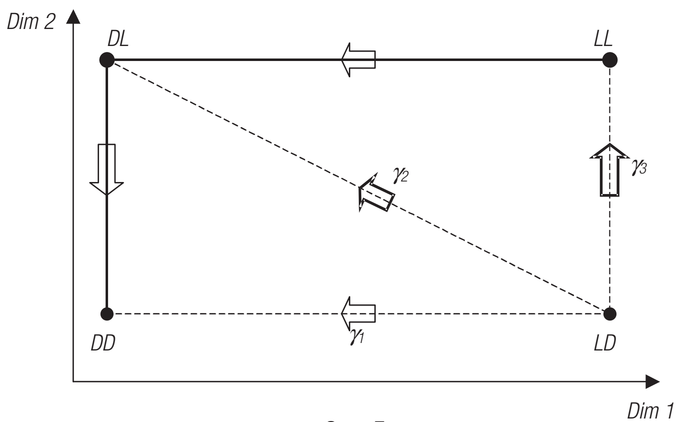


Figure 2 Upward Incentive Constraints



Case E

Using (4) and (2), one can see that for every effort (k_{ij}) the principal maximizes a quadratic function:

$$\varphi_{ij}^{k}(\zeta) = \max_{k \geq 0} p_k k_{ij} - \frac{\zeta}{4}(k_{ij})^2$$

where ζ depends on the binding incentive constraints and the type *ij* of the agent. The first part of this expression is simply the weighted output of the agent. The quadratic term includes two costs (hidden in ζ): the direct production cost of the agent and the indirect costs in terms of rents left to other agents. The indirect costs play a crucial role in what follows and are tricky to derive because they depend on the binding constraints, which in turn, depend on the efforts and rents of the various types. The optimal effort and the virtual welfare from this effort can be computed as functions of ζ:

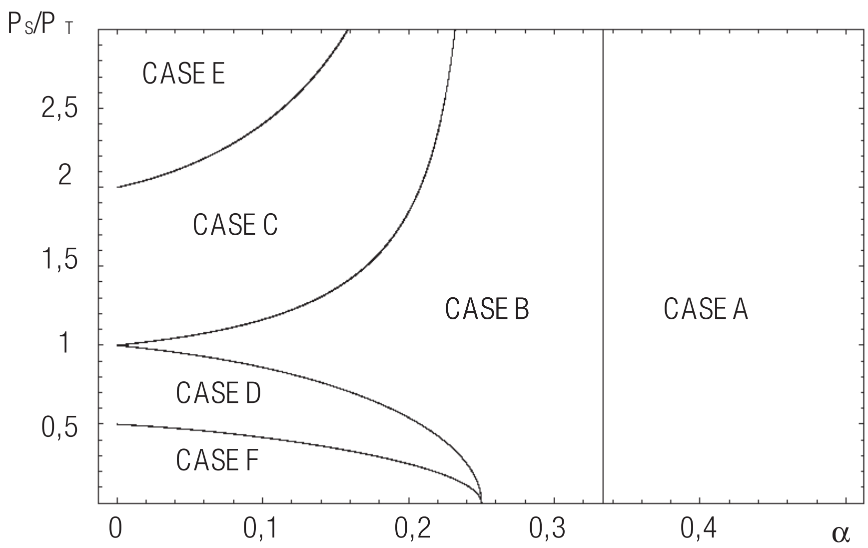
$$k_{ij}(\zeta) = \frac{2p_k}{\zeta} \qquad \varphi_{ij}^{k}(\zeta) = \frac{(p_k)^2}{\zeta}$$

B. *The main findings of Armstrong and Rochet (1999)*

This section summarizes the main conclusions of Armstrong and Rochet (1999). It will be shown that given our simplifying assumptions, their six cases can be summarized in a two-dimensional graph, then the driving force behind these cases will be briefly described.

Proposition 1 *None of the six mutually exclusive cases of Armstrong and Rochet (1999) is lost in our set-up. The areas where the cases are relevant are shown in Figure* 3 *where the axis of the graph are the correlation between types* (α) *and the relative weight of research and teaching in the objective function of the university* $\left(\frac{p_s}{p_t}\right)$.

Figure 3 Different Cases



Let us now summarize the main aspects of the six cases of Armstrong and Rochet (1999).

Case A:

— Holds when types are strongly positively correlated (when $\alpha > \frac{1}{3}$)
— All downward constraints bind: $LL \to LD$, $LL \to DL$, $LL \to DD$, $LD \to DD$, $DL \to DD$[15]
— An agent's effort on activity k depends solely on the type of the agent for activity k:

$$s_{DD}[A] = s_{DL}[A] = \frac{2}{3}p_s < \bar{s}_D \qquad s_{LL}[A] = s_{LD}[A] = \bar{s}_L$$

$$t_{DD}[A] = t_{LD}[A] = \frac{2}{3}p_t < \bar{t}_D \qquad t_{LL}[A] = t_{DL}[A] = \bar{t}_L$$

Case B:

— Holds when types are not too strongly correlated and when weights are similar, i.e., when $\frac{1}{4} < \alpha < \frac{1}{3}$ or when $\alpha < \frac{1}{4}$ and

$$I^{-1} \le \left(\frac{p_s}{p_t}\right)^2 \le I \qquad \text{where} \qquad I = \frac{(8\alpha+1)(1-\alpha)^2(1+2\alpha)^2}{[32\alpha^3 - 24\alpha^2 + 1]\,(4\alpha+1)^2}$$

— Four downward constraints bind: $LL \to LD$, $LL \to DL$, $LD \to DD$, $DL \to DD$
— Agents' efforts depend on their entire type (efforts are bundled together):

$$s_{DD}[B] < s_{DL}[B] < \bar{s}_D \qquad s_{LL}[B] = s_{LD}[B] = \bar{s}_L$$

$$t_{DD}[B] < t_{LD}[B] < \bar{t}_D \qquad t_{LL}[B] = t_{DL}[B] = \bar{t}_L$$

Case C (Case D is the mirror case of C when $p_t > p_s$):

— Holds when types are negatively correlated ($\alpha < \frac{1}{4}$) and when the principal puts the emphasis on science:

$$I < \left(\frac{p_s}{p_t}\right)^2 \le J \qquad \text{where} \qquad I = 4\frac{[1 + 8\alpha + 12\alpha^2]\,(1-\alpha)^2(1+2\alpha)^2}{[32\alpha^3 - 24\alpha^2 + 1]\,(4\alpha+1)^2}$$

— Three downward constraints bind: $LL \to DL$, $LD \to DD$, $DL \to DD$
— Agents' efforts depend on their entire type and LD agents furnish the efficient level of effort:

$$s_{DD}[C] < s_{DL}[C] < \bar{s}_D \qquad s_{LL}[C] = s_{LD}[C] = \bar{s}_L$$

$$t_{DD}[C] < t_{LD}[C] = \bar{t}_D \qquad t_{LL}[C] = t_{DL}[C] = \bar{t}_L$$

[15] Where $LL \to DD$ denotes the incentive constraints preventing LL to mimic DD.

Case E (Case F is the mirror case of E when $p_t > p_s$):

— Holds when types are negatively correlated ($\alpha < \frac{1}{4}$) and when the principal neglects teaching:

$$\left(\frac{p_s}{p_t}\right)^2 > J$$

— Some upward constraints bind (see Figure 2): $LL \to DL$, $DL \to DD$, $LD \to LL$, $LD \to DL$, $LD \to DD$

— *LD* agents furnish the efficient level of effort, *LL* and *LD* work more than the efficient level:

$$\begin{array}{ll} s_{DD}[E] < s_{DL}[E] \leq \bar{s}_D & s_{LL}[E] = s_{LD}[E] = \bar{s}_L \\ t_{DD}[E] < t_{LD}[E] = \bar{t}_D & t_{LL}[E] = t_{DL}[E] > \bar{t}_L \end{array}$$

C. *Does a single contract for teaching and research improve production?*

It has been shown that the main conclusions of Armstrong and Rochet (1999) are still valid in this simplified version; a subsection will be devoted to draw some conclusions for universities. This section concentrates on the determinants of the menu of contracts designed by the universities. The two central variables will be described first and then their effect on whether the *bundling mechanism* is used or not.

1. *The two central variables*

As in the above section, the menu of contracts proposed by the university to the academics can be grouped into six different cases depicted in Figure 3. Two variables are central to determine the relevant case: on the vertical axis, the relative weight of research in the institution $\left(\frac{p_s}{p_t}\right)$ and, on the horizontal axis, the probability that academics who like research also like teaching (the correlation of types, α).

In order to link the different cases with some real world example, one can consider the vertical axis as follows: the relative weight for teaching ranges from doctoral granting institutions[16] (above) to baccalaureate or associate colleges[17] (below).

Concerning the horizontal axis, going back to the arguments developed in Section 2, on the one hand, agents could *differ in their overall productivity*: some agents produce more output (research and teaching) for the same cost. This should be the case if what matters, in the end, is imagination, working hard, ability to express ideas clearly, etc. In this case, the types are positively correlated, α is high and the right of Figure 3 is relevant. On the other hand, if *time scarcity* is an important issue, the opportunity cost to do research increases with the time allocated to students. This

[16] As defined by the Carnegie Foundation for Advancement of Teaching: Institutions that typically offer a wide range of baccalaurate programs, and are committed to graduate education through the doctorate.

[17] As defined by the Carnegie Foundation for Advancement of Teaching: Institutions that are primarily undergraduate colleges with major emphasis on baccalaureate programs.

case is ruled out mathematically, since the marginal cost of effort on one task does not depend on the effort on the other task. However, time scarcity leads efforts to be strategic substitutes and one can show that, every other thing being equal, it leads an academic to devote her attention to the task where she has a comparative advantage. The presence of increasing returns to scale leverages this effect. In this case, α is low and the left of Figure 3 is relevant since those who *like* research probably *dislike* teaching and vice versa.

2. No bundling when the types are very positively correlated

If types are sufficiently positively correlated (because agents differ in their overall productivity), we are on the right of Figure 3. The Case A holds. There is no advantage to write a single contract for teaching *and* research: all decisions concerning research can be taken by observing research output only and all decisions concerning teaching can be taken by observing teaching output only. The expected production on one task depends only on the type of the agent for that task (s_{ij} depends solely on i since $s_{DL} = s_{DD}$ and t_{ij} depends solely on j since $t_{LD} = t_{DD}$).

In this case, the contracts are as previously described: high powered incentives, high efforts and high wages for the agents who *like* the tasks and low powered incentives, low efforts and low wage for the agents who *dislike* the tasks. Moreover, they have the same characteristics as the optimal contract when there is only one dimension. The screening literature has emphasized a fundamental trade-off between two conflicting objectives: maximize the surplus produced by the agents and minimize the part of this surplus used to remunerate the agents.

By lowering the expected output of the agents who *dislike* the task, the university reduces the surplus produced by these agents. But it will also enable the principal to reduce the corresponding expected wage, and hence, it reduces the attractiveness of the contract for the agents who *like* the task. If the attractiveness of the contract is reduced, the informational rent required to induce the agents who *like* the task to choose the right contract also decreases. So, for the principal, reducing the surplus produced by the agents who *dislike* the task makes it possible to reduce the informational rent of the agents who *like* the task. There is a trade-off between surplus produced and the part of this surplus that goes to the agents through the informational rent.

To sum up, when agents differ in their overall productivity and time scarcity is not an issue, the university maximizes the profit produced by requiring:

- A first-best level of output by the agents who *like* the task through a contract with high powered incentive schemes.
- An output that is below first-best level by the agents who *dislike* the task through a contract with low powered incentive schemes

3. The bundling mechanism when the types are not too positively correlated

Until now, the optimal contract was described when the types are very positively correlated, that is, when there is no benefit for the university to propose a single contract for research *and* teaching. In all the other cases, the university proposes a menu of contracts combining the production of research *and* teaching (s_{ij} depends on *i and* on *j* since $s_{DL} \neq s_{DD}$ and t_{ij} depends on *j and* on *i* since $t_{LD} \neq t_{DD}$). It can use a mechanism in which scholars who want to claim they like research (teaching) are expected, all other things being equal, to make more efforts on their teaching (research) tasks ($s_{DL} > s_{DD}$ and $t_{LD} > t_{DD}$). The tasks are bundled up in a single contract.

Why is bundling better for the principal when α is not too high, that is, when productivities for teaching and science differ? Let us give an intuition that will be proven in Proposition 2. In the absence of bundling, agents have two separate contracts for teaching and research. The agents who *like* both tasks (*LL*, call them *high types*) produce a first-best level of output on both activities. They get two informational rents (one per task). The agents who *like* only one task (*LD* and *DL*, call them *medium types*) produce a first-best level of output on one task (the one they *like*) and a level of output below first-best for the other task. They get a single informational rent to reveal that they *like* one of the tasks. The agents who *dislike* both tasks (*DD*, call them *low types*) get no informational rent and produce a level of output below first-best on both dimensions. As shown in the next subsections, the *bundling mechanism* uses the type of the agent on the second task in the following way:

— The institution induces the *medium* types (*LD* and *DL* types) to produce more output on the dimension they *dislike*; this *increases the surplus produced by the medium types*.

— By distorting the level of output of the *low* types (*DD* types) further downward, the principal decreases the minimal informational rent of the *medium* types (*LD* and *DL* types); this *decreases the share of surplus dedicated to the medium types*.

— These two effects lead to an *unambiguous increase in the profit* that the principal makes with the efforts *of the medium types*.

— However, distorting downward the level of output of the *low* types leads to a decrease in the surplus produced by the *low* types. Since the *low* types do not get any informational rent, this directly *reduces the profit* that the principal makes with the efforts *of the low types*.

— Seemingly, increasing the level of output of the *medium* types makes their contracts more attractive for the *high* types (*LL* types). This means that the principal must increase the informational rent of the *high* types so that they choose the contract designed for them. This *reduces the profit* that the principal makes with the efforts *of the high types*.

To sum up, the *bundling mechanism* increases the profit from the *medium* types and reduces the profit from the *low* and *high* types. The profit that the principal makes with the outputs of the *medium* types is more valuable if they represent an important part of the population, i.e., if α is low. Seemingly, when α is low, the profit of the *low* and *high* types is less important. So, below a threshold correlation ($\alpha = \frac{1}{3}$), the *bundling mechanism* is profitable for the principal because the profit increase from the *medium* types more than compensates the losses from the *high* and *low* types. Moreover, below this threshold, the usage of the *bundling mechanism* increases when α decreases.

It should be emphasized that the *bundling mechanism* does not mean that the university should reward one task only. The contracts designed by the principal must induce the agent to work on (and thus reward) both tasks but they should link the reward to the production of teaching *and* research.

D. The effects of bundling

1. Effects of bundling on efforts

Armstrong and Rochet (1999) is widely used and applied. They have simplified some technical complexities and have helped to understand the crucial importance of binding constraints. However, Armstrong and Rochet (1999) are silent on the comparison of the efforts across the six cases. It is not even clear whether the efforts and other relevant variables behave smoothly. In the following proposition, it is shown that the efforts are continuous and monotonic functions.

Proposition 2 *The efforts of the agents are continuous functions of p_t, p_s and α. They are either nondecreasing* (+) *or nonincreasing* (−) *functions of* α:

$$\begin{array}{ll} t_{LL} = t_{LL}(\alpha^-), & s_{LL} = s_{LL}(\alpha^-), \\ t_{LD} = t_{LD}(\alpha^-), & s_{LD} = s_{LD}(\alpha^-), \\ t_{DL} = t_{DL}(\alpha^-), & s_{DL} = s_{DL}(\alpha^-), \\ t_{DD} = t_{DD}(\alpha^+), & s_{DD} = s_{DD}(\alpha^+). \end{array}$$

Proof: See Appendix.

Corollary 1 *The rents of the medium types are continuous nondecreasing* (+) *functions of* α:

$$\begin{aligned} R_{LD} &= R_{LD}(\alpha^+), \\ R_{DL} &= R_{DL}(\alpha^+), \\ R_{DD} &= 0. \end{aligned}$$

Proof: $R_{LD} = R_{LD}(s_{DD}{}^+) = R_{LD}(s_{DD}(\alpha^+))$, $R_{DL} = R_{DL}(t_{DD}{}^+) = R_{DL}(t_{DD}(\alpha^+))$.

These results build on the *bundling mechanism* and deserve some comments. When α decreases, that is, if productivities for teaching and science differ, the proportion of *medium* types in the population increases. As pointed out earlier, the principal uses the *bundling mechanism* to strictly increase the profit she makes with these *medium* types. First, their efforts, and hence the surplus produced, increase on the tasks disliked by the *medium* types. Second, their informational rents (R_{ij}) decrease, because the efforts of the *low* types decrease. The profit of the principal from the *medium* types unambiguously increases since she increases the total surplus and increases her share of this surplus. The reverse holds concerning *low* types: efforts decrease to keep incentive compatibility of the *medium* types; this leads to a decrease in the surplus created. Proposition 2 proves the intuition of the previous subsection and shows that the use of the *bundling mechanism* increases continuously when α decreases, through the different cases of Armstrong and Rochet (1999). This helps also to understand the transition between these cases.

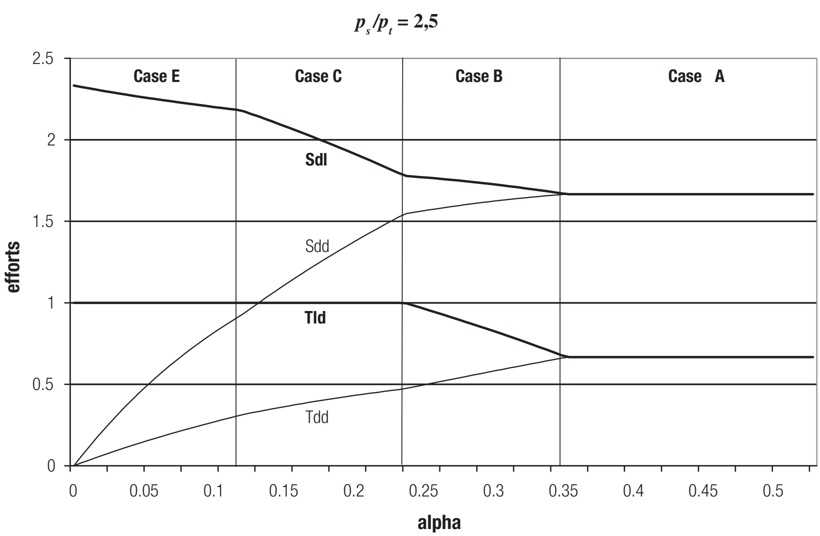
2. Effects of bundling on rents and surplus

Let us now turn to some numerical simulations of the efforts and rents of the agents in the different cases. These simulations give a general picture of the findings of the previous subsection but they also enable us to draw some new conjectures. The net effect of a reduction in the correlation on the surplus produced or on the informational rent of the *high* types could not be derived (analytically), since a reduction in the correlation has reverse effects on the efforts of the *medium* types and of the *low* types.

For the simulations, the weights were fixed in such a way that cases A, B, C and E are covered ($p_s = 2{,}5$ and $p_t = 1$).

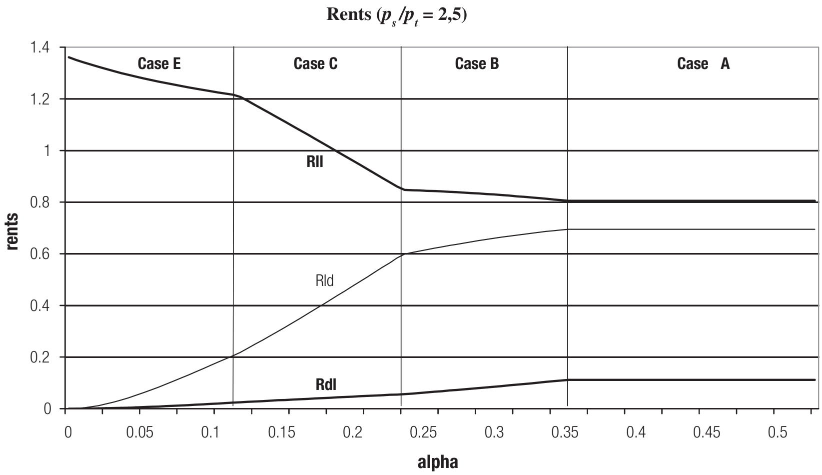
The simulation of the efforts on the task *disliked* (Figure 4) confirms the theoretical findings: a reduction in the correlation increases the efforts of the *medium* types and reduces the efforts of the *low* types. It is interesting to notice that, s_{DL} and s_{DD} are flatter when case B is relevant than when case C is relevant. As discussed in the proof of Proposition 2, when case B is relevant (and $p_s > p_t$), a decrease in the correlation has two opposite effects on the efforts on science: a direct effect and an indirect effect (through γ). When case C is relevant, the indirect effect disappears since γ is constant; leading to steeper curves. One could make a similar reasoning comparing case C and case E.

Figure 4 Efforts



The simulation of the informational rents presented in Figure 5 confirms the theoretical findings of the previous section for the *medium* types: their rents decrease when α decreases. Moreover, the rents of the *high* types increase when the correlation decreases.

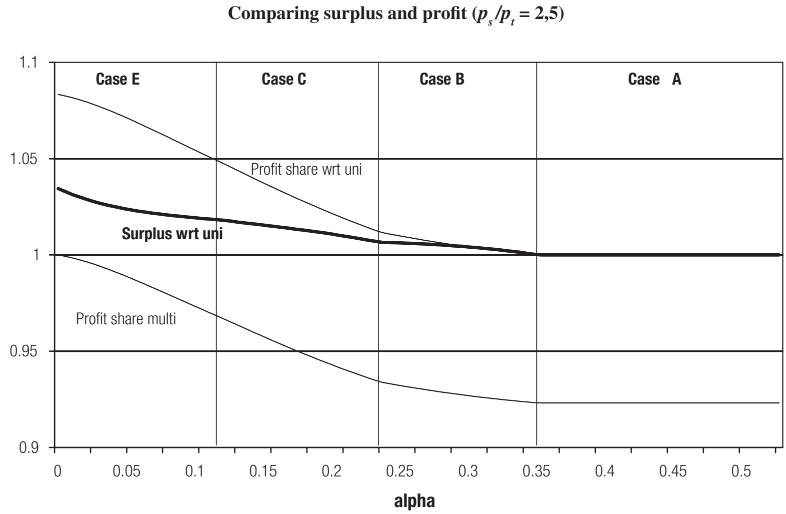
Figure 5 Rents



As already emphasized above, the correlation influences various parts of the profit. The intermediate curve of Figure 6 shows that the total surplus increases when α decreases. The *bundling mechanism* increases the total surplus since it is used more when α decreases. So, this mechanism is efficient from a social perspective: the use of the second dimension to screen agents reduces information inefficiencies. However, as one can see on the lowest curve of Figure 6, this increase in surplus is not distributed equally between the principal and the agents: the part of the surplus that falls to the monopsonist's share (the profit) increases when the correlation decreases. Finally, the upper curve shows the increase in profit made by a monopsonist using the two dimensions[18]. The monopsonist can increase her profit by up to nearly 15 % (if $\alpha = 0$) using the *bundling mechanism*. This combines the results of the two other curves: the monopsonist benefits of the increase of the total surplus created and of the increase of her profit share in the surplus.

[18] Case A corresponds to twice the unidimensional situation ("no bundling").

Figure 6 Surplus and Profit



The results of the simulations are summarized in Conjecture 1. The attempt was made to prove this result formally, but was not. As can be seen from the Appendix, the surplus relies on implicit equations and sign of its derivative could not be derived. The simulations, however, give clear results.

Conjecture 1 *The rents of LL agents, the total surplus produced by all agents, and the proportion of this surplus that falls in the principal's share (the profit) are continuous and decreasing functions of α. This can be observed on Figure 5 and Figure 6.*

E. Contracts when bundling occurs

In this section, I describe the optimal multidimensional contracts in universities more precisely and try to draw some conclusions relying on the different cases shown in Figure 3.

1. When the types are not too positively or too negatively correlated

If types are not too positively correlated or if the institution does not put the emphasis on either dimension, case B holds, and the university uses the *bundling mechanism*. *LL* are compensated for high production of teaching and research. *LD* get a lower compensation but produce less teaching (although more than *DD*). *DL* get a lower compensation than *LL* but produce less research (although more than *DD*). Finally, *DD* produce a small amount and get a small wage.

This has policy implications for careers in universities where the principal proposes contracts to separate the different types. If we have tenure track jobs in mind, the model shows that 'bundling up' both tasks is desirable: the introduction of teaching loads can help to screen researchers for tenure. It is better for the university to make the probability of tenure depend on both teaching *and* research outcomes.

Similarly, the decisions about the promotions of academics should take the entire production into account.

2. *When the types are negatively correlated*

A tight time constraint and/or increasing returns to effort on a task can be interpreted as a negative correlation of types. Then, different cases emerge depending on the relative emphasis on teaching and research in the institution.

For baccalaureate colleges[19], which are institutions that strongly put the emphasis on teaching ($p_t > p_s$), cases D and F apply. In both cases, universities should elicit an efficient level of output (for science also) from the *teachers* (agents *DL* who dislike science and like teaching). This happens because the *bundling mechanism* is taken to its limit for the teachers. The principal increases their production on the task they dislike (science) up to the first-best level. Since they like teaching, they also produce a first-best level of output on this activity.

In case E, when the institution disregards science ($p_t \gg p_s$), agents who like science produce inefficiently high levels of research output. This surprising result of Armstrong and Rochet (1999) appears for incentive purposes. The contract designed for *researchers* (agents who like science, *LL* and *LD*) should be unattractive in order to reduce the rent of the *teachers*. The easiest way to render the contract unattractive for agents who dislike science is to increase the required level of output on this task, because the marginal cost of effort on this task is high for these agents. Armstrong and Rochet show that this increase of output leads to an output above the first-best level.

It is important to remember that it is assumed that the agents have very poor outside options and that institutions use their bargaining power to design contracts in a way that favors their interests. The result for *researchers* (who should overwork in baccalaureate colleges) should not be over-emphasized because researchers prefer working in a research university and won't turn to a baccalaureate college. What is robust, however, is that a baccalaureate college should not design a too attractive contract for researchers.

If the institution does not put the emphasis on either of her tasks, which can be interpreted as master's colleges and universities[20], we are back to the case B described in the previous section.

If the institution puts the emphasis on science ($p_s > p_t$), which can be interpreted as doctoral or research universities,[21] cases C and E are relevant. This is the mirror situation of cases D and F with $p_s > p_t$. Again, in both cases, all academics who like science are asked to teach at an efficient level for them because the *bundling mecha-*

[19] As defined by the Carnegie Foundation for Advancement of Teaching: Institutions that are primarily undergraduate colleges with major emphasis on baccalaureate programs.

[20] As defined by the Carnegie Foundation for Advancement of Teaching: Institutions that typically offer a wide range of baccalaurate programs, and are committed to graduate education through the masters degree.

[21] As defined by the Carnegie Foundation for Advancement of Teaching: Institutions that typically offer a wide range of baccalaurate programs, and are committed to graduate education through the doctorate.

nism is taken to its limit for the "pure researchers" (agents *LD* who like science and dislike teaching). Moreover, if case E is to hold, the institution requires more output than would be optimal on teaching from academics who like to teach. Again, the lesson of this model is not that those agents will work more than is optimal in a research university. Pure researchers probably find positions in baccalaureate colleges and do not apply in a research university. But, research universities should not design attractive contracts for them because this increases the informational rents left to academics who like science.

F. The optimal contract between a university and the government

Until now, the focus has been on the relationship between an academic and a university. However, it is possible to reinterpret the model to analyze the relation between a university and the subsidizing principal. Most universities get subsidies from their government. As in our model, the principal (government) has an important bargaining power, and can approximately observe output. This output can be seen as a deterministic function of effort: uncertainty decreases because of large numbers. However, universities differ in characteristics that are not observed by the government. The government can observe the output of a university, but it is much more difficult to observe some characteristics like: a better internal organization, intrinsically more productive academic staff, ability to raise external funds, etc.

The model suggests that the government can take advantage of its bargaining power to design a menu of incentive contracts. Moreover, it is possible to shed some light on the design of the optimal menu depending on the correlation of the characteristics and on the relative focus on teaching and research.

Let us first consider the case where the correlation is high between the ability to organize efficiently the production of teaching and research. This case is well suited for high-level teaching and research. The results at the Teaching Quality Assessment (TQA) and at the Research Assessment Exercise (RAE) are very correlated (see Qamar uz Zaman, 2004 and Grunig, 1997): they both depend on the amount of money spent, and it is easier for the prestigious institutions to raise funds for various reasons (numerous and powerful alumni, for instance). Moreover, it is easier to attract productive academics when there is already a pool of prestigious academics because academics value the exchanges with talented colleagues (they coordinate on certain institutions). Since education is a consumer-input good in which peers influence the quality of education, students tend also to coordinate. Taking this into account, the quality of education and research are subject to coordination and some institutions have an absolute advantage over others.

In this case of high correlation, the principal cannot benefit from the bundling mechanism. There is no advantage to link subsidies for research and teaching. In particular, it is not inefficient to separate funding and evaluation agencies. Our model suggests that the British model in which teaching and research are evaluated and rewarded separately (TQA and RAE) cannot be improved upon through the bundling of the two tasks.

Schimank and Winnes (2000) indicate that European countries have evolved in different directions regarding the “bundling” of research and teaching in universities. There are, however, two main trends: basic research remains in universities (or go to universities[22]) and universities are moving toward what the authors call a “post-Humboldtian pattern”. In the “post-Humboldtian pattern”, research and teaching are organized in the same institution but are funded separately. This is efficient from a screening perspective in the case of high correlation because first, it is rational to produce both outputs in the institutions which have a comparative advantage in the production and, second, the funding agencies do not gain anything from coordination.

If institutions well organized to produce teaching do not produce research efficiently, we are in another situation. A majority of students do not go to world leading universities, but to some other higher education institutions, some of which provide good teaching services (given the funds invested) and others do not. One can doubt of the very positive correlation of teaching and research in this case. When types are slightly positively correlated or negatively correlated, the model described in this paper suggests to bundle up the tasks.

The principal can take advantage of its bargaining power and propose contracts that include research *and* teaching. This enables her to screen one dimension using the other. In particular, if the government puts the emphasis on teaching, it should elicit a higher level of research from the institutions which are well designed to produce education. Another lesson from the model is that the government should be careful when it proposes contracts to research universities in this case: too attractive contracts would increase the rents of teaching colleges.

5. Conclusion

This paper has discussed the problem of contract design for academics working on two tasks, the production of science and teaching. Most existing papers study the ex post moral hazard problem and suggest to separate tasks. In this paper, the ex ante selection problem was studied and it was shown that universities may want to design a single contract for the production of science and teaching. They can then use the *bundling mechanism* to separate academics who like research (for instance): they introduce (relatively) higher teaching loads to screen researchers. It is then useful for the university that the probability of getting tenured depends on both teaching *and* research outcomes.

It is shown that the *bundling mechanism* is profitable if the types of the agents are not too positively correlated. Some sections discuss the correlation of types: it is argued that time constraints lead the types to be negatively correlated, while overall productivity leads types to be positively correlated. Although, no direct empirical investigation assesses the correlation of types, some indirect evidence is provided that shows that the *bundling mechanism* can be used in universities.

[22] They report, for instance, that France has only recently encouraged research teams to locate in universities.

There are at least two nice avenues for future research. The first one leads to evaluate the influence of the number of candidates for a position. This can be studied in a multidimensional auctions setting (see, for instance, Asker and Cantillon, 2006). It is highly probable that the main conclusions will not change. A second nice area of research would be to study contract design in a more competitive environment, where the outside option of academics is not symmetric across tasks. If outside options depend more on the ability to do research than on the ability to teach (a natural assumption), the optimal contract designed by universities may be modified in favor of researchers. A growing literature studies the link between types and outside options but authors usually consider a single type (see Lewis and Sappington, 1989; Jullien, 2000; Rochet and Stole, 2002).

Appendix: Proof of Proposition 1 and 2

Proof: The incentive compatibility constraints are given by

$$\begin{aligned} R_{ij} &= w_{ij} - \frac{1}{2}\left(c_i^s\left(s_{ij}\right)^2 + c_j^t\left(t_{ij}\right)^2\right) \geq w_{i'j'} - \frac{1}{2}\left(c_i^s\left(s_{i'j'}\right)^2 + c_j^t\left(t_{i'j'}\right)^2\right) \\ \Leftrightarrow R_{ij} &\geq R_{i'j'} - \frac{1}{2}\left(\left(c_i^s - c_{i'}^s\right)\left(s_{i'j'}\right)^2 + \left(c_j^t - c_{j'}^t\right)\left(t_{i'j'}\right)^2\right) \end{aligned} \tag{6}$$

where $ij \neq i'j'$.

The profit decreases with rents (3) and $R_{DD} = 0$. In cases A, B, C and D, when no upward constraints bind, the rents of the *medium* types (*LD* and *DL*) are

$$R_{LD} = R_{DD} + \frac{1}{2}\left(\left(t_{DD}\right)^2 - c_L^t\left(t_{DD}\right)^2\right) = 0 + \Delta\left(t_{DD}\right) = \frac{\left(t_{DD}\right)^2}{4} \tag{7}$$

$$R_{DL} = R_{DD} + \frac{1}{2}\left(\left(s_{DD}\right)^2 - c_L^s\left(s_{DD}\right)^2\right) = 0 + \Delta\left(s_{DD}\right) = \frac{\left(s_{DD}\right)^2}{4} \tag{8}$$

Rents of *LL* types are:

$$R_{LD} = \max\left[\left\{\begin{array}{l} R_{DD} + \frac{1}{4}\left(2\left(s_{DD}\right)^2 - \left(s_{DD}\right)^2\right) \\ R_{DL} + \frac{1}{4}\left(2\left(s_{DL}\right)^2 - \left(s_{DL}\right)^2 + \left(t_{DL}\right)^2 - 2\left(t_{DL}\right)^2\right) \\ R_{LL} + \frac{1}{4}\left(\left(t_{DD}\right)^2 - 2\left(t_{DD}\right)^2\right) \end{array}\right\}\right]$$

$$R_{LL} = \max\left\{\begin{array}{l} \Delta\left(t_{DD}\right) + \Delta\left(s_{DD}\right) \\ \Delta\left(t_{DD}\right) + \Delta\left(s_{DL}\right) \\ \Delta\left(t_{LD}\right) + \Delta\left(s_{DD}\right) \end{array}\right\} = \frac{1}{4}\max\left\{\begin{array}{l} \left(t_{DD}\right)^2 + \left(s_{DD}\right)^2 \\ \left(t_{DD}\right)^2 + \left(s_{DL}\right)^2 \\ \left(t_{LD}\right)^2 + \left(s_{DD}\right)^2 \end{array}\right\} \tag{9}$$

The objective of the principal (3) is rewritten using (7), (8) and (9) with $S_{ij} = S_{ij}^s + S_{ij}^t$:

$$
\begin{aligned}
&\alpha\left\{S_{DD} - R_{DD} + S_{LL} - R_{LL}\right\} + \left(\frac{1}{2} - \alpha\right)\left\{S_{DL} - R_{DL} + S_{LD} - R_{LD}\right\}\\
&\alpha\left\{S_{LL} - R_{LL} + S_{DD} - R_{DD}\right\} + \left(\frac{1}{2} - \alpha\right)\left\{S_{LD} - R_{LD} + S_{DL} - R_{DL}\right\}\\
&= \alpha\left\{p_s s_{DD} + p_t t_{DD} - \frac{1}{4}\left(2\left(s_{DD}\right)^2 + 2\left(t_{DD}\right)^2\right)\right\}\\
&+\left(\frac{1}{2} - \alpha\right)\left\{p_s s_{DL} + p_t t_{DL} - \frac{1}{4}\left(2\left(s_{DL}\right)^2 + \left(t_{DL}\right)^2 + \left(t_{DD}\right)^2\right)\right\}\\
&+\left(\frac{1}{2} - \alpha\right)\left\{p_s s_{DL} + p_t t_{DL} - \frac{1}{4}\left(2\left(t_{LD}\right)^2 + \left(s_{LD}\right)^2 + \left(s_{DD}\right)^2\right)\right\}\\
&+\alpha\left\{p_s s_{LL} + p_t t_{LL} - \frac{1}{4}\left(\left(s_{LL}\right)^2 + \left(t_{LL}\right)^2\right) - \frac{1}{4}\begin{bmatrix}\gamma_1\left(\left(s_{DD}\right)^2 + \left(t_{DD}\right)^2\right) +\\ \gamma_2\left(\left(s_{DL}\right)^2 + \left(t_{DD}\right)^2\right) +\\ \gamma_3\left(\left(s_{DD}\right)^2 + \left(t_{LD}\right)^2\right)\end{bmatrix}\right\}
\end{aligned}
\tag{10}
$$

where the $\gamma_i \geq 0$ are a kind of Lagrangian multiplier associated with the downward constraints that are not always binding. $\gamma_i = 0$ if the relevant constraint does not bind and $\gamma_i > 0$ if the relevant constraint binds.

For example, as shown in Figure 1, γ_1 is associated with the incentive constraint which ensures that *LL* prefer the contract designed for them to the one designed for *DD*. $\gamma_1 = 0$ if $(t_{DD})^2+(s_{DD})^2 < (s_{DL})^2+(t_{DD})^2$ or if $(t_{DD})^2+(s_{DD})^2 < (s_{DD})^2+ (t_{LD})^2$ and $\gamma_1 > 0$ if $(t_{DD})^2 + (s_{DD})^2 \geq (s_{DL})^2 + (t_{DD})^2$ and $(t_{DD})^2 + (s_{DD})^2 \geq (s_{DD})^2 +(t_{LD})^2$.

Moreover,

$$\gamma_1 + \gamma_2 + \gamma_3 = 1 \tag{11}$$

Equation (10) can be separated for the different efforts:

$\varphi_{ij}^k\left(\zeta\right) = \max_{k\geq 0} p_k k_{ij} - \frac{\zeta}{4}\left(k_{ij}\right)^2$ where ζ depends on the binding incentive constraints and the type *ij* of the agent. This problem has a unique solution:

$$\hat{k}\left(\zeta\right) = \frac{2p_k}{\zeta} = \hat{k}\left(\zeta^-\right) \tag{12}$$

Equations (10), (11) and (12) lead to the following expressions for the efforts:

$$
\begin{gathered}
s_{LL} = s_{LD} = \overline{s}_L = \hat{s}\left(1\right)\\
t_{LL} = t_{DL} = \overline{t}_L = \hat{t}\left(1\right)
\end{gathered}
\tag{13}
$$

$$s_{DL} = \hat{s}\left(\frac{2 - 2\alpha\left(2 - \gamma_2\right)}{1 - 2\alpha}\right) = s_{DL}\left(\alpha^-, \gamma_2^-\right) \tag{14}$$

$$t_{LD} = \hat{t}\left(\frac{2 - 2\alpha\left(2 - \gamma_3\right)}{1 - 2\alpha}\right) = t_{LD}\left(\alpha^-, \gamma_3^-\right) \tag{15}$$

$$s_{DD} = \hat{s}\left(\frac{1+2\alpha\left(2-\gamma_2\right)}{2\alpha}\right) = s_{DD}\left(\alpha^+,\gamma_2^+\right) \tag{16}$$

$$t_{DD} = \hat{t}\left(\frac{1+2\alpha\left(2-\gamma_3\right)}{2\alpha}\right) = t_{DD}\left(\alpha^+,\gamma_3^+\right) \tag{17}$$

As can be seen in (14) through (17), the efforts of the agents depend on the binding constraints. In what follows, the methodology of Armstrong and Rochet (1999) is applied using the six different cases (A to F). It is shown that the efforts are continuous on separation line between the cases.

Case A is the situation where all 'downward' incentive constraints bind. By definition of γ_i, this implies that $\gamma_i > 0\ \forall\ i$ and

$$\Delta\left(s_{DD}\right)+\Delta\left(t_{DD}\right)=\Delta\left(s_{DL}\right)+\Delta\left(t_{DD}\right)=\Delta\left(s_{DD}\right)+\Delta\left(t_{LD}\right)$$

$$\Leftrightarrow \mathrm{s}_{DD} = \mathrm{s}_{DL} \text{ and } \mathrm{t}_{DD} = \mathrm{t}_{LD} \Leftrightarrow \text{(by (14) to (17))}\ \gamma_2 = \gamma_3 = \frac{1-2\alpha}{2\alpha}$$

$$\Leftrightarrow \mathrm{s}_{\mathrm{DD}} = \mathrm{s}_{\mathrm{DL}} = \hat{s}\left(3\right) = \frac{2}{3}p_s \qquad \text{and} \qquad \mathrm{t}_{\mathrm{DD}} = \mathrm{t}_{\mathrm{LD}} = \hat{t}\left(3\right) = \frac{2}{3}p_t \tag{18}$$

It remains to be checked that what we assumed initially ($0<\gamma_i< 1\ \forall\ i$) is satisfied:

$$0 < \gamma_2 = \gamma_3 = \frac{1-2\alpha}{2\alpha} < 1 \Leftrightarrow \frac{1}{4} < \alpha < \frac{1}{2}$$

$$0 < \gamma_1 = 1-\gamma_2-\gamma_3 < 1 \Leftrightarrow \frac{1}{3} < \alpha < \frac{1}{2}$$

Case B is the situation where the only 'downward' incentive constraint which does not bind is the one to deter *LL* to mimic *DD*. By definition of γ_i, $\gamma_1 = 0$ and γ_2, $\gamma_3 > 0$. Define $\gamma = \gamma_2$ and, by (11), $\gamma_3 = 1 - \gamma$.

$0 < \gamma < 1$ if

$$\Delta\left(s_{DL}\right)+\Delta\left(t_{DD}\right)=\Delta\left(s_{DD}\right)+\Delta\left(t_{LD}\right) \tag{19}$$

$$\Delta\left(s_{DL}\right)+\Delta\left(t_{DD}\right)\geq\Delta\left(s_{DD}\right)+\Delta\left(t_{DD}\right) \tag{20}$$

$$\Delta\left(s_{DD}\right)+\Delta\left(t_{LD}\right)\geq\Delta\left(s_{DD}\right)+\Delta\left(t_{DD}\right) \tag{21}$$

From (20) and (21), one can deduce that $s_{DL} \geq s_{DD}$ and $t_{LD} \geq t_{DD}$ so that (19) can be rewritten as

$$\left(s_{DL}\right)^2-\left(s_{DD}\right)^2=\left(t_{LD}\right)^2-\left(t_{DD}\right)^2$$

$$\Leftrightarrow \left(\frac{p_s}{p_t}\right)^2\left[\left(\frac{1-2\alpha}{1-\alpha\left(2-\gamma\right)}\right)^2-\left(\frac{4\alpha}{1+2\alpha\left(2-\gamma\right)}\right)^2\right] \tag{22}$$

$$=\left[\left(\frac{1-2\alpha}{1-\alpha\left(1+\gamma\right)}\right)^2-\left(\frac{4\alpha}{1+2\alpha\left(2+\gamma\right)}\right)^2\right] \tag{23}$$

We will now prove that for every pair $\left(\frac{p_s}{p_t},\alpha\right)$ there is one and only one γ such that (22) = (23) is satisfied. The partial derivatives of the different efforts (wrt γ and α) computed in (14) through (17) are

$$\begin{aligned}
&\frac{\partial s_{DL}}{\partial\alpha}=\frac{-p_s\gamma}{\left(1-\alpha\left(2-\gamma\right)\right)^2}\leq 0 &&\frac{\partial s_{DL}}{\partial\gamma}=\frac{-p_s\alpha\left(1-2\alpha\right)}{\left(1-\alpha\left(2-\gamma\right)\right)^2}\leq 0\\
&\frac{\partial t_{LD}}{\partial\alpha}=\frac{-p_t\left(1-\gamma\right)}{\left(1-\alpha\left(1+\gamma\right)\right)^2}\leq 0 &&\frac{\partial t_{LD}}{\partial\gamma}=\frac{p_t\left(1-2\alpha\right)}{\left(1-\alpha\left(1+\gamma\right)\right)^2}\geq 0\\
&\frac{\partial s_{DD}}{\partial\alpha}=\frac{4p_s}{\left(1+2\alpha\left(2-\gamma\right)\right)^2}\leq 0 &&\frac{\partial s_{DD}}{\partial\gamma}=\frac{8p_s\alpha^2}{\left(1+2\alpha\left(2-\gamma\right)\right)^2}\leq 0\\
&\frac{\partial t_{DD}}{\partial\alpha}=\frac{4p_t}{\left(1+2\alpha\left(1+\gamma\right)\right)^2}\leq 0 &&\frac{\partial t_{DD}}{\partial\gamma}=\frac{-8p_t\alpha^2}{\left(1+2\alpha\left(1+\gamma\right)\right)^2}\geq 0
\end{aligned} \tag{24}$$

for $\left(\gamma,\alpha\right)\in\left[0,1\right]\times\left[0,\frac{1}{2}\right]$. Using partial derivatives, (22) and (23) are functions of γ for every $\left(\frac{p_s}{p_t},\alpha\right)$: $\left(s_{DL}\left(\gamma^-\right)\right)^2-\left(s_{DD}\left(\gamma^+\right)\right)^2=\left(t_{LD}\left(\gamma^+\right)\right)^2-\left(t_{DD}\left(\gamma^-\right)\right)^2$ or (22)(γ^-) = (23)(γ^+). Since both sides are continuous, we know that the function $1>\gamma\left(\frac{p_s}{p_t},\alpha\right)>0$ is uniquely determined by (22) = (23) if

$$(22)(\gamma)\geq(23)(\gamma)\qquad\text{when } \gamma=0, \tag{25}$$

$$\text{and}\qquad(22)(\gamma)\leq(23)(\gamma)\qquad\text{when } \gamma=1. \tag{26}$$

This is checked by plugging (14) through (17) with $\gamma_2=\gamma=0=\gamma_1$ and $\gamma_3=1$ into (25). The inequality reduces to

$$\left(\frac{p_s}{p_t}\right)^2\geq\frac{\left[32\alpha^3-24\alpha^2+1\right]\left(4\alpha+1\right)^2}{\left(8\alpha+1\right)\left(1-\alpha\right)^2\left(1+2\alpha\right)^2}$$

which is always satisfied when $\alpha>\frac{1}{4}$ since the (23) is negative. Using the same method, (26) reduces to

$$\left(\frac{p_s}{p_t}\right)^2\frac{\left[32\alpha^3-24\alpha^2+1\right]\left(4\alpha+1\right)^2}{\left(8\alpha+1\right)\left(1-\alpha\right)^2\left(1+2\alpha\right)^2}\leq 1$$

which always satisfied when $a > \frac{1}{4}$ since (22) is negative.

$\gamma\left(\frac{p_s}{p_t}, \alpha\right)$ is continuous in $a = \frac{1}{3}$: (18) implies that $\gamma_2 = \gamma_3 = \frac{1}{2}$ and $\gamma_1 = 0$ when $\alpha = \frac{1^+}{3}\left(\forall \frac{p_s}{p_t}\right)$. Moreover, $\gamma\left(\frac{p_s}{p_t}, \frac{1^-}{3}\right) = \frac{1}{2}\left(\forall \frac{p_s}{p_t}\right)$ satisfies (22) = (23) when $\alpha = \frac{1^-}{3}$ since both sides of the equation reduce to zero at the limit.

Efforts (14) through (17) are continuous in $a = \frac{1}{3}$ because of the continuity of $\gamma(\alpha)$ in $a = \frac{1}{3}$ and (14) through (17).

If $\frac{p_s}{p_t} = 1, \gamma(\alpha) = \frac{1}{2}\ \forall\alpha$ satisfies (22) = (23).

It will now be shown that for a given price ratio $\frac{p_s}{p_t}$

$$\gamma = \gamma(\alpha^-) \Leftrightarrow \frac{p_s}{p_t} > 1$$

$$\gamma = \gamma(\alpha^+) \Leftrightarrow \frac{p_s}{p_t} < 1$$

The partial derivatives (24) imply that

— $\gamma(\alpha^+) \Rightarrow$ (22) (α^-) and there are two opposite effects for (23): $\frac{\partial}{\partial\alpha}(23) < 0$ and $\frac{\partial}{\partial\gamma}(23) > 0$.

— $\gamma(\alpha^-) \Rightarrow$ (23) (α^-) and there are two opposite effects for (22): $\frac{\partial}{\partial\alpha}(22) < 0$ and $\frac{\partial}{\partial\gamma}(22) > 0$

Fix $\frac{p_s}{p_t} > 1$, start from $a = \frac{1}{3}$ and $\gamma\left(\frac{p_s}{p_t}, \frac{1}{3}\right) = \frac{1}{2}$, let a decrease, moving toward the left on Figure 3 up to the intersection with case C where $\gamma = 1$. When $\frac{p_s}{p_t} > 1$, (22) = (23) $\Leftrightarrow \gamma(\alpha)$ puts a downward pressure on the *LHS* and an upward pressure on the *RHS* $\Leftrightarrow \gamma(\alpha^-)$.

This implies

— $\frac{p_s}{p_t} > 1 \Rightarrow \frac{\partial t_{LD}}{\partial\alpha} < 0$ and $\frac{\partial t_{DD}}{\partial\alpha} > 0$ and $\frac{\partial s_{LD}}{\partial\alpha} < 0$ or $\frac{\partial s_{DD}}{\partial\alpha} > 0$ to satisfy (22) = (23). Numerical simulations show that both hold.

— $\frac{p_s}{p_t} < 1 \Rightarrow \frac{\partial s_{DL}}{\partial \alpha} < 0$ and $\frac{\partial s_{DD}}{\partial \alpha} > 0$ and $\frac{\partial t_{LD}}{\partial \alpha} < 0$ or $\frac{\partial t_{DD}}{\partial \alpha} > 0$ to satisfy (22) = (23). Numerical simulations show that both hold.

Case C occurs if $\gamma_1 = \gamma_3 = 0$ and $\gamma_2 = 1$. Plugging this into (14) through (17) gives

$$\begin{aligned} s_{DL} &= \hat{s}\left(\frac{2(1-\alpha)}{1-2\alpha}\right) = \frac{p_s(1-2\alpha)}{1-\alpha} & s_{DD} &= \hat{s}\left(\frac{1+2\alpha}{2\alpha}\right) = \frac{4\alpha\, p_s}{1+2\alpha} \\ t_{LD} &= \hat{t}(2) = \bar{t}_D = p_t & t_{DD} &= \hat{t}\left(\frac{1+4\alpha}{2\alpha}\right) = \frac{4\alpha\, p_t}{1+4\alpha} \end{aligned} \tag{27}$$

It remains to be proven that upward constraints are satisfied; that is

$$LD \text{ not } DL \qquad R_{LD} \geq R_{DL} + \Delta(s_{DL}) - \Delta(t_{DL})$$

$$\Leftrightarrow \Delta(t_{DL}) - \Delta(t_{Dd}) \geq \Delta(s_{DL}) - \Delta(s_{DD}), \tag{28}$$

$$DL \text{ not } LD \qquad R_{DL} \geq R_{LD} + \Delta(s_{LD}) - \Delta(t_{LD})$$

$$\Leftrightarrow \Delta(\bar{s}_{DL}) - \Delta(s_{DD}) \geq \Delta(t_{LD}) - \Delta(t_{DD}), \tag{29}$$

$$LD \text{ not } LL \qquad R_{LD} \geq R_{LL} - \Delta(t_{LL})$$

$$\Leftrightarrow \Delta(t_{LL}) - \Delta(t_{DD}) \geq \Delta(s_{DL}) - \Delta(s_{DD}), \tag{30}$$

where (28) through (30) is established using (6) and (7) through (9).

Equation (13) ensures that (28) is equivalent to (30).

Equation (28) is equivalent to (5) if the efforts are replaced by their value in (27).

It becomes clear now that when (5) is not satisfied, some upward constraints ((28) and (30)) are violated.

Equation (29) is satisfied since

$$\Delta(\bar{s}_L) - \Delta(s_{DD}) > \Delta(s_{DL}) - \Delta(s_{DD}) \geq \Delta(t_{LD}) - \Delta(t_{DD})$$

where the first inequality holds by definition of $\Delta(\cdot)$ and of $\bar{s}_L$ and the second inequality must hold by definition of γ_i when $\gamma_2 = 1$ and $\gamma_3 = 0$.

Finally, efforts are continuous on the separation line between case B and case C: for a given price ratio $\frac{p_s}{p_t} > 1$ when α decreases toward the separation between case B and case C, $\gamma_2 \to 1$ and $\gamma_3 \to 0$. Efforts of case B tend towards efforts in case C (27).

Other cases. Besides case D (symmetric of case C where $\gamma_1 = 1$ and $\gamma_2 = \gamma_3 = 0$), all other cases are impossible without upward binding constraints. Proof by contradiction:

Suppose $\gamma_2 = 0$ and $\gamma_1, \gamma_3 > 0$. It implies (by definition of γ_i) that

$$\Delta(s_{DD}) + \Delta(t_{DD}) = \Delta(s_{DD}) + \Delta(t_{LD}) \Leftrightarrow t_{LD} = t_{DD}$$
$$\Delta(s_{DD}) + \Delta(t_{DD}) > \Delta(s_{DL}) + \Delta(t_{DD}) \Leftrightarrow s_{DD} > s_{DL}$$

Plugging $\gamma_2 = 0$ into (14) leads to $s_{DL} = \overline{s}_D \Rightarrow s_{DD} > s_{DL}$ is possible by (16) if $\frac{1}{2\alpha} < 0$, which is impossible.

Similar impossibilities arise for $\gamma_3 = 0$ and $\gamma_1, \gamma_2 > 0$ and $\gamma_2 = \gamma_3 = 0$ and $\gamma_1 = 1$.

Case E (The proof is similar to the proof of case B) When case E holds, some upward constraints must be taken into account and the rents are:

$$R_{DD} = 0$$

$$R_{DL} = R_{DD} + \frac{1}{4}\left(2\left(t_{DD}\right)^2 - \left(t_{DD}\right)^2\right) = 0 + \Delta\left(t_{DD}\right) = \frac{\left(t_{DD}\right)^2}{4}$$

$$R_{LL} = R_{DL} + \frac{1}{4}\left(2\left(s_{DL}\right)^2 - \left(s_{DL}\right)^2\right) = \Delta\left(t_{DD}\right) + \Delta\left(s_{DL}\right) = \frac{\left(t_{DD}\right)^2}{4} + \frac{\left(s_{DL}\right)^2}{4},$$

$$R_{LD} = \max\left\{\begin{matrix} R_{DD} + \frac{1}{4}\left(2\left(s_{DD}\right)^2 - \left(s_{DD}\right)^2\right) \\ R_{DL} + \frac{1}{4}\left(2\left(s_{DL}\right)^2 - \left(s_{DL}\right)^2 + \left(t_{DL}\right)^2 - 2\left(t_{DL}\right)^2\right) \\ R_{LL} + \frac{1}{4}\left(\left(t_{DD}\right)^2 - 2\left(t_{DD}\right)^2\right) \end{matrix}\right\}$$

$$R_{LL} = \max\left\{\begin{matrix} \Delta\left(s_{DD}\right) \\ \Delta\left(t_{DD}\right) + \Delta\left(s_{DL}\right) - \Delta\left(t_{DL}\right) \\ \Delta\left(t_{DD}\right) + \Delta\left(s_{DL}\right) - \Delta\left(t_{LL}\right) \end{matrix}\right\} = \frac{1}{4}\max\left\{\begin{matrix} \left(s_{DD}\right)^2 \\ \left(t_{DD}\right)^2 + \left(s_{DL}\right)^2 - \left(t_{DL}\right)^2 \\ \left(t_{DD}\right)^2 + \left(s_{DL}\right)^2 - \left(t_{LL}\right)^2 \end{matrix}\right\}.$$

This means that the objective function of the principal (3) can be rewritten as follows:

$$\begin{aligned}
&\alpha\left\{S_{DD} - R_{DD} + S_{LL} - R_{LL}\right\} + \left(\frac{1}{2} - \alpha\right)\left\{S_{LD} - R_{LD} + S_{DL} - R_{DL}\right\} = \\
&\alpha\left\{p_s s_{DD} + p_t t_{DD} - \frac{1}{4}\left(2\left(s_{DD}\right)^2 + 2\left(t_{DD}\right)^2\right)\right\} \\
&+\left(\frac{1}{2} - \alpha\right)\left\{p_s s_{DL} + p_t t_{DL} - \frac{1}{4}\left(2\left(s_{DL}\right)^2 + \left(t_{DL}\right)^2 + \left(t_{DD}\right)^2\right)\right\} \\
&+\alpha\left\{p_s s_{LL} + p_t t_{LL} - \frac{1}{4}\left(\left(s_{LL}\right)^2 + \left(t_{LL}\right)^2 + \left(s_{DL}\right)^2 + \left(t_{DD}\right)^2\right)\right\} \\
&+\left(\frac{1}{2} - \alpha\right)\left\{p_s s_{LD} + p_t t_{LD} - \frac{1}{4}\left(\left(s_{LD}\right)^2 + \left(t_{LD}\right)^2\right) - \frac{1}{4}\left[\begin{matrix} \gamma_1\left(s_{DD}\right)^2 + \\ \gamma_2\left(\left(t_{DD}\right)^2 + \left(s_{DL}\right)^2 - \left(t_{DL}\right)^2\right) + \\ \gamma_3\left(\left(t_{DD}\right)^2 + \left(s_{DL}\right)^2 - \left(t_{LL}\right)^2\right) \end{matrix}\right]\right\}
\end{aligned}$$

where the $\gamma_i \geq 0$ are again a kind of Lagrangian multiplier: in particular $\gamma_i = 0$ if the related constraint (see Figure 2) does not bind and $\gamma_1 + \gamma_2 + \gamma_3 = 1$.

The efforts are:

$$s_{LL} = s_{LD} = \overline{s}_L = 2p_s$$

$$t_{LL} = \hat{t}\left(\frac{2\alpha - \gamma_3(1-2\alpha)}{2\alpha}\right) \geq \overline{t}_L = 2p_t$$

$$t_{DL} = \hat{t}(1-\gamma_2) \geq \overline{t}_L = 2p_t$$

$$s_{DL} = \hat{s}\left(\frac{1+(1-2\alpha)(2-\gamma_1)}{1-2\alpha}\right)$$

$$t_{LD} = \hat{t}(2) = \overline{t}_D = p_t$$

$$s_{DD} = \hat{s}\left(\frac{4\alpha + \gamma_1(1-2\alpha)}{2\alpha}\right)$$

$$t_{DD} = \hat{t}\left(\frac{2+2\alpha - \gamma_1(1-2\alpha)}{2\alpha}\right)$$

$\gamma_i > 0 \ \forall i$ if

$$\Delta(t_{DD}) + \Delta(s_{DL}) - \Delta(t_{DL}) = \Delta(t_{DD}) + \Delta(s_{DL}) - \Delta(t_{LL}) \tag{32}$$

$$\Delta(t_{DD}) + \Delta(s_{DL}) - \Delta(t_{DL}) = \Delta(s_{DD}) \tag{33}$$

$$\Delta(t_{DD}) + \Delta(s_{DL}) - \Delta(t_{LL}) = \Delta(s_{DD}) \tag{34}$$

Using (31) and (32), one can see that $\frac{1-2\alpha}{2\alpha}\gamma_3 = \gamma_2$ and (33) is equivalent to (34).

Using (34) one can redefine the γ_i, $\gamma_2 = \gamma$, $\gamma_3 = \frac{2\alpha}{1-2\alpha}\gamma$, $\gamma_1 = \frac{1-\gamma - 2\alpha}{1-2\alpha}$ and $0 < \gamma < 1 - 2\alpha$.

The partial derivatives of the efforts with respect to α and γ are

$$\begin{aligned}
&\frac{\partial s_{DL}}{\partial \alpha} = \frac{-4p_s(1+\gamma)}{\left(2(1-\alpha)+\gamma\right)^2} \leq 0 &\qquad& \frac{\partial s_{DL}}{\partial \gamma} = \frac{-2p_s(1-2\alpha)}{\left(2(1-\alpha)+\gamma\right)^2} \leq 0 \\
&\frac{\partial t_{LD}}{\partial \alpha} = 0 && \frac{\partial t_{DL}}{\partial \gamma} = \frac{2p_t}{(1-\gamma)^2} \geq 0 \\
&\frac{\partial s_{DD}}{\partial \alpha} = \frac{4p_s(1-\gamma)}{(1+2\alpha-\gamma)^2} \geq 0 && \frac{\partial s_{DD}}{\partial \gamma} = \frac{4p_s\alpha}{(1+2\alpha-\gamma)^2} \geq 0 \\
&\frac{\partial t_{DD}}{\partial \alpha} = \frac{4p_t(1+\gamma)}{(1+4\alpha+\gamma)^2} \geq 0 && \frac{\partial t_{DD}}{\partial \gamma} = \frac{-8p_t\alpha^2}{\left(1+2\alpha(1+\gamma)\right)^2} \leq 0
\end{aligned} \tag{35}$$

for $(\gamma,\alpha) - [0,1]\times\left[0,\frac{1}{2}\right]$.

Let us rewrite (33) as

$$\Delta(t_{DL}) - \Delta(t_{DD}) = \Delta(s_{DL}) - \Delta(s_{DD}), \tag{36}$$

where, by definition of Δ and (35), for every pair $\left(\frac{p_s}{p_t}, \alpha\right)$, the *RHS* increases with γ ($RHS(\gamma^+)$) and the *LHS* decreases with γ ($LHS(\gamma^-)$). This means that there is a unique equilibrium γ for every pair $\left(\frac{p_s}{p_t}, \alpha\right)$ if the two following conditions are satisfied: $LHS < RHS$ when $\gamma = 0 \Leftrightarrow \Delta(\bar{t}_L) - \Delta(t_{DD}) < \Delta(s_{DL}) - \Delta(s_{DD})$ which is satisfied since, firstly, when $\gamma = 0$ ($\Leftrightarrow \gamma_1 = \gamma_2 = 0$ and $\gamma_3 = 1$) we are back to the efforts of case C as can be checked comparing (31) and (27) and, second, (5) or (28) does not hold by definition of case E.

$$LHS > RHS \text{ when } \gamma = 1 - 2\alpha \Leftrightarrow \gamma_1 = 0$$

$$\Leftrightarrow \Delta(t_{DL}) - \Delta(t_{DD}) > \Delta(\bar{t}_L) - \Delta(t_{DD}) > 0 > \Delta(s_{DL}) - \Delta(\bar{s}_D).$$

Equation (36) defines a function $\gamma\left(\frac{p_s}{p_t}, \alpha\right)$. As discussed above, when $\gamma = 0$ we are on the separation curve between case C and E where there is no discontinuity in the efforts. Departing from this curve, and moving to the left in Figure 3 (keeping $\frac{p_s}{p_t}$ constant), γ increases ($\gamma = \gamma(\alpha^-)$): indeed, $\gamma \geq 0$ and $\gamma = 0$ on the separation curve. Reducing the correlation α leads to an increase in γ up to the point where $\alpha = 0$ where $s_{DD} = t_{DD} = 0$ (as can be checked using (31) and (36)) reduces to $\frac{p_s}{p_t} = \frac{2+\gamma}{1-\gamma}$. The *RHS* of (36) unambiguously increases as α decreases, and by the equality, the *LHS* also increases. There are two countervailing effects on the *LHS*: the direct effect $\left(\text{trough } \frac{\partial}{\partial\alpha}\right)$ puts an upward pressure and the indirect effect $\left(\text{trough } \frac{\partial}{\partial\gamma}\right)$ puts and a downward pressure on the *LHS*.

$\frac{\partial t_{LD}}{\partial\alpha} < 0$ and $\frac{\partial t_{DD}}{\partial\alpha} > 0$ since the partial effects of $\gamma(\alpha)$ and α go in the same direction. Equation (23) holds if $\frac{\partial s_{LD}}{\partial\alpha} < 0$ and $\frac{\partial s_{DD}}{\partial\alpha} > 0$. Numerical simulations show that both hold.

References

ARMSTRONG M. & J.-C. ROCHET (1999), "Multi-dimensional screening: a user's guide", *European Economic Review*, 43, pp. 959-979.

ASKER J. & E. CANTILLON (2006). *Procurement when price and quality matter* (mimeo ECARES).

AVERY C. & T. J. HENDERSHOTT (2000), "Bundling and the optimal auctions of multiple products", *Review of Economics Studies*, 67, pp. 483-497.

BARBEZAT D. A. & M. R. DONIHUE (1998), "Do faculty salaries rise with job seniority?", *Economic Letters*, 58, pp. 239-244.

Baumol W. J., J. C. Panzar, & R. D. Willig (1982), *Contestable markets and the theory of industry structure*, Harcourt Brace Jovanovich, New York.

Becker W. E. (1997), "Teaching economics to undergraduates", *Journal of Economic Literature*, 35, pp. 1347-1373.

Becker W. E. & P. Kennedy (2004), *Does teaching enhance research in economics*, Presentation at the University of South Australia.

Becker W. E. & M. Watts (1999), "How departments of economics evaluate teaching", *The American Economic Review Papers and Proceedings*, 89, pp. 344-349.

Bodenhorn H. N. (1997), "Teachers, and scholars too: economic scholarship at elite liberal arts colleges", *Journal of Economic Education*, 28, pp. 323-336.

Bodenhorn H. N. (2003), "Economic scholarship at elite liberal arts colleges: a citation analysis with rankings", *Journal of Economic Education*, 34, pp. 341-359.

Bonaccorsi A., C. Daraio, & L. Simar (2006), "Advanced indicators of productivity of universities. An application of robust nonparametric methods to Italian data", *Scientometrics*, 66, pp. 389-410.

Brown R. B. (2004), *Why link your personal research and your teaching*? Presentation at the Colloquium: Research and Teaching: Closing the Divide?

Bryant L. J. (2004), "Editor's note", *Indiana University, Research & Creative Activity*, 26(2).

Carlton D. W., G. E. Bamberger & R. J. Epstein (1995), "Antitrust and higher education: was there a conspiracy to restrict financial aid", *RAND Journal of Economics*, 26, pp. 131-147.

Coaldrake P. & L. Stedman (1999), *Academic work in the twenty-first century. Changing roles and policy* (Occasional Paper and Series), Department of Education, Training and Youth.

Cohn E., L. W. Sherrie, & M. C. Santos, (1989), "Institutions of higher education as multi-product firms", *The Review of Economics and Statistics*, 71, pp. 284-290.

Colbeck C. L. (1998), "Merging a seamless blend. How faculty integrate teaching and research", *The Journal of Higher Education*, 69, pp. 647-670.

Cowen T. & S. Papenfuss (1997). *Why are most universities not-for-profit*? (Working Paper No 97.04). George Mason University Department of Economics.

Dasgupta P. & P. A. David (1994), "Toward a new economics of science", *Research Policy*, 23, pp. 487-521.

Dasgupta P. & E. Maskin (1987), "The simple economics of research portfolios", *The Economic Journal*, 97, pp. 581-595.

David P. A. (1998), "Common agency contracting and the emergence of "open science" institutions", *The American Economic Review Papers and Proceedings*, 88, pp. 15-21.

Dearden J., L. Taylor, & R. Thornton (2001), "A benchmark profile of economics departments in 15 private universities", *Journal of Economic Education*, 32, pp. 387-396.

de Groot H., W. W. McMahon, & F. Volkwein (1991), "The cost structure of American research universities", *The Review of Economics and Statistics*, 73, pp. 424-431.

Dewatripont M., I. Jewitt, & J. Tirole (2000), "Multitask agency problems: focus and task clustering", *European Economic Review*, 44, pp. 869-877.

Dewatripont M., F. Thys-Clément, & L. Wilkin (2001), "Managing university complexity" In: M. Dewatripont, F. Thys-Clément, & L. Wilkin (Eds.), *European universities: change and convergence?,* Editions de l'Université de Bruxelles, Brussels.

Diamond A. M. (1993), "Economic explanations of the behavior of universities and scholars", *Journal of Economic Studies*, 20, pp. 107-133.

Dundar H. & D. R. Lewis (1995), "Departmental productivity in American universities: economies of scale and scope", *Economics of Education Review*, 14, pp. 119-144.

Dundar H. & D. R. Lewis (1998), "Determinants of research productivity in higher education", *Research in Higher Education*, 39, pp. 607-631.

Elton L. (2001), "Research and teaching: conditions for a positive link", *Teaching in Higher Education*, 6, pp. 43-56.

Euwals R. & M. E. Ward (2000), *What matters most: teaching or research? Empirical evidence on the remuneration of British academics* (CEPR Discussion Paper No. 2628).

Goldin C. & L. F. Katz (1999), "The shaping of higher education: the formative years in the United States, 1890 to 1940", *Journal of Economic Perspectives*, 13, pp. 37-62.

Gottlieb E. E. & B. Keith (1997), "The academic research-teaching nexus in eight advanced industrialized countries", *Higher Education*, 34, pp. 397-419.

Grunig S. D. (1997), "Research, reputation, and resources. The effect of research activity on perceptions of undergraduate education and institutional resource acquisition", *Journal of Higher Education*, 68, pp. 17-52.

Hallock K. F. (1995), "Seniority and monopsony in the academic labor market: comment", *The American Economic Review*, 85, pp. 654-657.

Hare P. G. & G. Wyatt (1992), "Economics of academic research and its implications for higher education", *Oxford Review of Economic Policy*, 8, pp. 48-68.

Hattie J. A. C. & H.W. Marsh (1996), "The relationship between research and teaching — a meta-analysis", *Review of Educational Research*, 66, pp. 507-542.

Hattie J. A. C. & H.W. Marsh (2004), *One journey to unravel the relationship between research and teaching*, Presentation at the Colloquium: Research and Teaching: Closing the Divide?

Holmstrom B. & P. Milgrom (1991), "Multitask principal-agent analyses: incentive contracts, asset ownership, and job design" *Journal of Law, Economics and Organization*, 7, pp. 24-51.

Jullien B. (2000), "Participation constraints in adverse selection models", *Journal of Economic Theory*, 93, pp. 1-47.

Koshal R. K. & M. Koshal (1999), "Economies of scale and scope in higher education: a case of comprehensive universities", *Economics of Education Review*, 18, pp. 269-277.

Lenoir T. (1998), "Revolution from above: the role of the state in creating the German research system, 1810-1910", *The American Economic Review Papers and Proceedings*, 88, pp. 22-27.

Lewis T. R. & D. E. M. Sappington (1989), "Countervailing incentives in agency problems", *Journal of Economic Theory*, 49, pp. 294-313.

Mas-Colell A. (2003), "The European space of higher education: incentive and governance issues", *Rivista di Politica Economica*, 93, pp. 9-27.

Masten S. E. (1995), "Old school ties: financial aid coordination and the governance of higher education" *Journal of Economic Behavior and Organization*, 28, pp. 23-47.

Masten S. E. (1999), *Commitment and political governance: why universities, like legislatures, are not organized as markets* (University of Michigan Business School WP).

Mitchell J. E. & D. S. Rebne (1995), "Nonlinear effects of teaching and consulting on academic research productivity", *Socio-Economic Planning Sciences*, 29, pp. 47-57.

Neumann R. (1994), "The teaching-research nexus: applying a framework to university students' learning experiences", *European Journal of Education*, 29, pp. 323-338.

Noser T. C., H. Manakyan & J. R. Tanner (1996), "Research productivity and perceived teaching effectiveness: a survey of economics faculty", *Research in Higher Education*, 37, pp. 299-321.

Qamar uz Zaman M. (2004), *Review of the academic evidence on the relationship between teaching and research in higher education* (Research Report RR506), Department for Education and Skills, Nottingham.

Ransom M. R. (1993), "Seniority and monopsony in the academic labor market", *The American Economic Review*, 83, pp. 221-233.

Rochet J.-C. & L. A. Stole (2002), "Nonlinear pricing with random participation", *Review of Economic Studies*, 69, pp. 277-311.

Schimank U. & M. Winnes (2000), "Beyond Humboldt? The relationship between teaching and research in European university systems", *Science and Public Policy*, 27, pp. 397-408.

Stephan P. E. (1996), "The economics of science", *Journal of Economic Literature*, 34, pp. 1199-1235.

Tullock G. (1993), "Are scientists different?", *Journal of Economic Studies*, 20, pp. 90-106.

Teaching versus research: The role of internal financing rules in multi-department universities

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Summary

In this paper, we combine the multi-department structure which characterises universities with the multitasking nature of the academic's incentive problem. We show by mean of an example that a conglomerate structure in the university may actually be instrumental in inducing high efforts from the academic in its two basic activities. Accordingly, depending on the shape of its preference, the university may implement various combinations of teaching and research outputs by altering the incentive package it offers to academics.

1. Introduction

Universities count teaching *and* research as part of their core social goals and, in an ideal world, one would like to see any university to excel in both dimensions. As a matter of fact, universities may also specialize on the mass teaching segment or the research oriented one and very little is known about how effective universities are in achieving either the ideal of combining teaching and research or the more limited objectives they retain. While some evidences from UK (see Shattock, 2002) point to universities which perform very well in research as well as in teaching, it is hard to obtain a more general picture, i.e. to see what happens exactly in those less prestigious universities. The situation is even more opaque in many continental systems where university assessment is in its very enfancy. As argued by Neary *et al.* (2003), it is widely accepted that "... poor governance structures and inappropriate incentives... still characterize so many European Universities" (p. 1240).

Combining high quality teaching and high quality research is actually desirable for the universities themselves, in particular in a system where universities are mostly financed on a per student basis and where students' choice depends on (1) teaching quality and (2) university's prestige (which is related to research quality). However, combining high quality teaching and high quality research is often viewed

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as a source of conflict within universities taken as an aggregate. And as a matter of fact, one may observe that some institutions tend to specialize into teaching activities while others are mostly known for their research achievements.

An obvious reason why research and teaching objectives look conflictual is that at the individual level, an academic cannot perform the two tasks simultaneously. The share of an academic's time which goes to teaching cannot go for research and vice versa. While part of the problem might be solved at the level of a university by specialising academics' tasks, it is often believed that full specialization is not desirable because the activities are complementary in nature. More fundamentally, the tensions between teaching and research activities come from the fact that teaching activities is a crucial source of revenues for universities, especially in continental Europe where the bulk of an institution's budget comes from subsidies and tuition fees that are directly related to the number of students. Under such a financing rule, teaching is costly because it leaves less time for research but it is nevertheless profitable, and necessary, because it raises money which may ultimately finance research. Notice that a key feature of such a system is the existence of cross-subsidization from teaching sectors to research ones.

Very different factors contribute to explain the universities' actual choice regarding research and teaching quality levels. Among those, the preferences of the universities, their culture, play a crucial role: some universities count mass teaching as their primary mission and will particularly emphasize on that dimension while others will try to excel in their research activities, and might devote little attention to their teaching duties. But the choice of teaching and research level is for sure a constrained one. Even for a university which wants to focus a lot on research, completely neglecting teaching is not possible when the financing of higher education institutions is based mainly on the number of students. Although the resulting trade-off between teaching and research activities has not been widely investigated in the literature, recent contributions in the area definitely put the budget constraint at the heart of the analysis, i.e. the way they formalize the university governance problem is essentially a matter of raising funds on the teaching side to spend money on research activities (see Beath *et al.*, 2005).

Del Rey (2001) models competition between universities who decide on the allocation of funds between teaching and research activities. In her model, teaching achievements and research records enter the university objective function and funding is positively related to the number of students. She studies the balance between research and teaching efforts as a function of the funding rules, which actually determine the scope for research through the financing raised on students. De Fraja and Iossa (2002) point out that the increased students' mobility favors the emergence of "elite" institutions, i.e. a limited number of high research records universities coexisting with other universities focusing on teaching activities. In these two papers, the presence of competition between universities is central to the argument. Beath *et al.* (2003) focus on the tensions between pure and applied research under binding budget constraints. However, the teaching side of the academics' job is not considered in their paper. Beath *et al.* (2005) analyze the impact of the higher education funding on the universities' choice regarding teaching and research intensities. In particular, they study the impact of a research quality based funding for the academics [2] on research and teaching level. They show that an increase in the research quality related funding (and a corresponding decrease in the per student subsidy) leads to the specialization of universities in either – world class – research and minimal quality teaching or minimal research and higher quality teaching. University specialization implies that there is no longer universities that perform (fairly) good in both dimensions.

A common feature of the above mentioned papers is their focus on external forces to explain the organization of teaching and research within universities. In the present paper, we focus instead on the internal organization of the university and specifically on its implication for the coexistence of teaching and research activities. The paper is organized around two simple ideas. First, universities are active in several disciplines and typically organize teaching and research by relying on departments. Most often though, the budget is centralized and the resource constraint applies at the university level. It means that the allocation of resources is done at the university level too. Thus, universities rely on an internal financing system which is very similar to the internal capital market of a conglomerate firm (see Coupé, 2001). Second, within each department, academics have to perform both research and teaching activities. While they choose the efforts they put in these two tasks, their choices might be governed by the incentives schemes provided by the authority. In this sense, the possible conflict between teaching and research is akin to a multitasking problem.

In Gautier and Wauthy (2007) we study in details the extent to which incentive schemes can be designed to take advantage of the conglomerate structure of multi-department universities. We show in particular that internal financing rules can be used to create yardstick competition and thereby enhance both teaching and research efforts. In this paper, we develop an example in which we show that depending on the shape of its preference, the university may implement various combinations of teaching and research outputs by altering the incentive package it offers to academics.

2. Model

We consider a university composed of N departments. Each department is responsible for adding to the stock of knowledge in its field through research activities and for disseminating that stock through its teaching activities. The quality of research and the quality of teaching of a department depend on the human and the financial resources spent on each task. In each department, there is a unique academic who is responsible of research and the teaching efforts.

The research output of department i, denoted hereafter by R_i, is defined as $R_i = r_i(b_i)^{1-h}$, where r_i is the research effort of the academic i and b_i is the research budget of the department. We further assume $h < 1$ so that the marginal productivity of money is decreasing. Notice that a larger value for h means that, other things being equal, money is less essential as an input for research.

[2] Like the research assessment exercises periodically performed in the UK.

Student's enrollment in department i increases with the teaching quality. The latter being a function of the teaching effort exerted by the academic i. If we denote the teaching effort in department i by t_i, we assume that the number of students enrolled in that department (n_i) is $n_i = t_i$.

Each student registered in the university contributes to the university budget by an amount $\bar{s}$. $\bar{s}$ is the sum of the student's tuition fee and the government per-student subsidy (if any). The overall budget of the university B is then $B = \bar{s}\sum_{k=1}^{N} n_k + F$ where F represents all the university resources which are not tied to the number of students. B is entirely redistributed to departments as research funds. The departments have no other resources than those coming from the university's central budget.

The allocation of resources to departments is decided at the university level by its central authority. The allocation of B to the departments will be based on two different criteria. A fraction γ of the university's budget B will be distributed to departments according to the relative qualities of their research projects, that is a research-based allocation of funds. The remaining fraction $1 - \gamma$ will be allocated according the relative qualities of the teaching programs, that is a student-based allocation of funds. In particular, we assume that each department i receives a research budget b_i given by:

$$b_i = \left(\gamma \frac{r_i}{\sum_{k=1}^{N} r_k} + (1-\gamma)\frac{t_i}{\sum_{k=1}^{N} t_k}\right)B \qquad (2.1)$$

Let us call $\alpha_i = \frac{r_i}{\sum_{k=1}^{N} r_k}$ and $\beta_i = \frac{t_i}{\sum_{k=1}^{N} t_k}$; hence $b_i = (\gamma\alpha_i + (1-\gamma)\beta_i)B$.

The above expression stresses the fact that in our model, it is indeed the *relative* quality of teaching and research which matters. Notice also that we assume all departments to be identical. Therefore they will exert the same efforts. This allows us to focus precisely on the role that can be assigned to competition accross departments per se [3]. Hence, at the equilibrium we will have $\alpha_i = \beta_i = \frac{1}{N}$ $\forall i$. and all the academics will have the same research budget $b_i = \frac{B}{N} = \bar{s}t_i + \frac{F}{N}$. However, the university's financing rule (γ) will have an impact on the incentives to perform tasks and therefore on the efforts level as we will explain in the next section. A key feature of the paper is the assumption that departments react to incentives and that the allocation of financial resources influences their choices of effort in both the teaching and the research task.

An academic i derives a private benefit from his research output. These private benefits are for example, notoriety, promotion, job opportunities,... By contrast, we assume that the academic does not derive any private benefit from his teaching achievement i.e it does not pay to be a good teacher. Accordingly, the academic's utility function is defined as follows:

$$U_i = \omega R_i - \frac{t_i^2 + r_i^2}{2}, \qquad (2.2)$$

[3] We of course acknowledge that the existence of a significant heterogeneity among academic departments may actually play a very significant role.

where ωR_i is the private benefit the academic enjoys when he achieves a research output R_i and $\frac{t_i^2 + r_i^2}{2}$ is the cost of performing a teaching effort t_i and a research effort r_i.

The specification of the academic's problem is of course extreme. It clearly makes the worst case for teaching effort in the sense that the only channel through which teaching efforts can be incentivized rests on the funding it raises for research. Notice also that this specification of the academic's preferences fits reasonably well with the view of a market for academics where research outputs are more valuable than teaching abilities: while research outputs are easily evaluated, and attached to individuals through external peer reviewing processes, teaching efforts are less easily transferred out of the institution and are thereby less valuable in the market. Notice also that we assume that there are no synergies, either positive or negative, between research and teaching efforts.

A. *Incentives*

Each academic i will select the level of efforts (t_i, r_i) in order to maximize his/her utility. Integrating the university's financing rule in the utility function, each academic i solves:

$$\max_{t_i, r_i} \omega r_i \left(\left(\gamma \frac{r_i}{\sum_{k=1}^{N} r_k} + (1-\gamma) \frac{t_i}{\sum_{k=1}^{N} t_k} \right) B \right)^{1-h} - \frac{t_i^2}{2} - \frac{r_i^2}{2} \tag{2.3}$$

For convenience, we consider that the university's budget has no other resources than those coming from the students, that is $F = 0$. The first order conditions of the above problem read as follows:

$$t_i = \omega r_i (1-h)(b_i)^{-h} \left((\gamma \alpha_i + (1-\gamma)\beta_i) \frac{\partial B}{\partial t_i} + B(1-\gamma) \frac{\partial \beta_i}{\partial t_i} \right) \tag{2.4}$$

$$r_i = \omega (b_i)^{1-h} + \omega r_i (1-h) b_i^{-h} \left(\gamma B \frac{\partial \alpha_i}{\partial r_i} \right). \tag{2.5}$$

Integrating the fact that all academics are identical, that is $t_i = t$, $r_i = \mathrm{r}$, $\forall i = 1, \ldots, N$, the first order conditions can be expressed as:

$$t = \omega r \bar{s}^{1-h} (1-h) t^{-h} g_1(N, \gamma), \tag{2.6}$$

$$r = \omega \bar{s}^{1-h} t^{1-h} g_2(N, \gamma), \tag{2.7}$$

where $g_1(N, \gamma) = \left(\frac{\gamma}{N} + (1-\gamma) \right)$ and $g_2(N, \gamma) = \left(1 + \frac{N-1}{N} \gamma (1-h) \right)$. In these first order conditions, the left hand sides are the marginal costs of respectively teaching and research efforts, the right hand sides are the marginal benefits of these two tasks. We are now in a position to discuss the *incentiv*e effect of the financing rule i.e. how the marginal benefit of each task is affected by the structure of university. This is the object of our first proposition.

Proposition 2.1

1. *The efforts on the two tasks are complements.*
2. *The marginal benefit of teaching effort is decreasing with the number of academics N and with γ.*
3. *The marginal benefit of research effort is increasing with the number of academics N and with γ.*

Part 1 of the proposition states that the effort on one task stimulates the effort on the other task. Recall that the production of research output requires the combination of two inputs: research effort and research funds. Notice then that research funds in department *i* increase with the teaching effort in that department, though in a proportion that depends on the university's financing rule. Since the marginal productivity of each of these two inputs increases with the quantity available of the other input, more effort on one task increases the incentives to supply effort on the other task i.e. teaching and research efforts are complements. Importantly, this complementarity is created by the university's financing rule since it establishes a link between teaching effort and research funding. Hence, even if the two tasks are independent in the academic's cost function, the university's financing rules create a complementarity between the two tasks.

The logic behind the model is best captured by considering the marginal benefit of teaching. In this respect, the conglomerate structure of the university might be a problem. Indeed it is likely to weaken incentives towards teaching. Redistribution of funds between departments lowers the academics' incentives to contribute to the university's budget i.e. to attract students through a high quality teaching. The benefit of an additional student – the additional tuition fee – will be redistributed to the *N* departments of the university and the academic will receive only a fraction $\gamma\alpha_i + (1-\gamma)\beta_i < 1$. Clearly, the fact that the academic does not fully capture the benefit of his/her teaching effort hurts the incentives. This effect is particularly important when *N* is large because each academic receives a fraction 1/N of the total budget. It is also more important when γ is larger. The parameter γ is an important incentive tool that has a dual impact on incentives: negative for teaching and positive for research. A large γ means that competition for research fund is intense and it therefore stimulates the incentives to perform research effort. More efforts on research might then induce more efforts on teaching because of complementarity. Conversely, a low γ means that a large fraction of the budget is secured in the department that managed to attract the students and as such, it is a strong incentive for teaching effort.

We are now equipped to characterize the optimal effort levels and study their dependence to the basic parameters of the model.

B. Efforts

Using equations (2.6), (2.7), it is immediate to obtain:

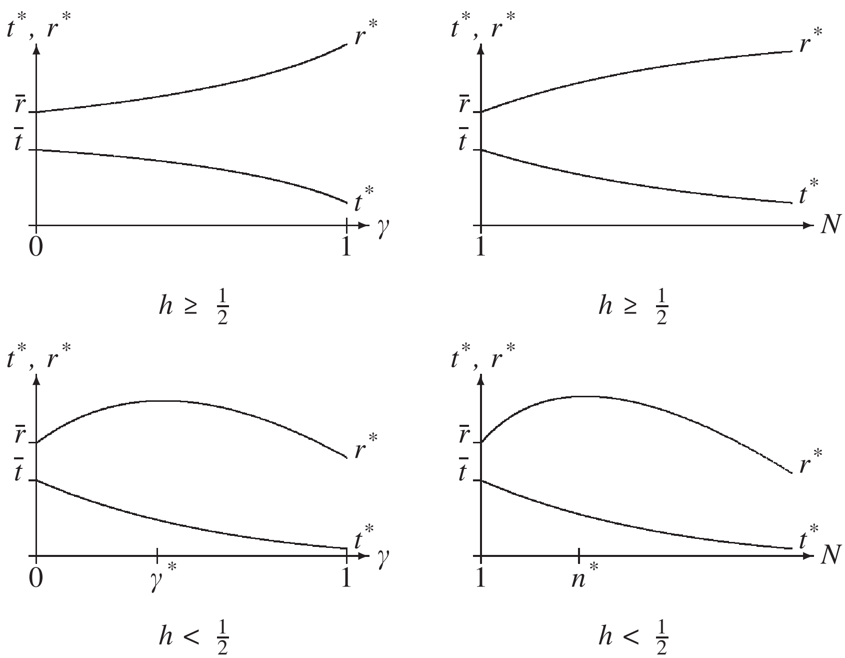
$$t^* = \bar{t}\left[g_1(\gamma, N)^{\frac{1}{2h}}\ g_2(\gamma, N)^{\frac{1}{2h}}\right] \tag{2.8}$$

$$r^* = \bar{r}\left[g_1(\gamma, N)^{\frac{1}{h}}\ g_2(\gamma, N)^{\frac{1-h}{h}}\right] \tag{2.9}$$

where $\bar{t}$ and $\bar{r}$ denote the optimal values for efforts in the limiting case where $N = 1$ and $\gamma = 0$, i.e. in the case where there is only one department (i.e. no redistribution takes place) and funding is exclusively depending on students' enrollment. Direct computations indicate:

Proposition 2.2

1. *The optimal teaching effort (t^*) decreases with the number of academics N and decreases with γ.*
2. *(a) If $h \geq \frac{1}{2}$, the optimal research effort (r^*) increases with the number of academics N and increases with γ.*
   (b) If $h < \frac{1}{2}$, the optimal research effort either always increases with γ and N or is non-monotonic



Notice that when h is small the shape of r^* is non-monotonic. Recall indeed that a smaller h actually means that the marginal contribution of money to research output is large, other things being equal. Since the positive effect of the conglomerate structure on research efforts hangs on the presence of yardstick competition between departments, the effect is very quickly eroded whenever a small part of the total budget is subject to research competition (γ is large) or when the benefits of competition are widely diluted (N is large).

C. Production frontiers

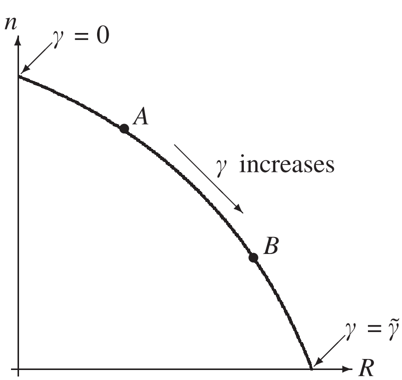
We explained in the previous section how different organizational structures for a university – both in term of number of academics/departments and in term of financing rule γ – result in different levels of teaching and research efforts. Our model also allows to characterize the different output combinations the university can achieve a a function of the internal organization it endorses. Our university produces two different outputs: graduated students in quantity t^* and scientific research in quantity R in each of the N departments. Notice that when we measure the teaching output by the number of students only, we put aside an important dimension of teaching: the students' acquired ability when they exit university. The latter depends obviously on teaching quality but also on the student's ability at the entrance and on the (average) quality of the cohort (peer effect). Most often, universities are not indifferent to the types of student they enroll. However, we neglect these (important!) effects in our framework and the university does not actively control the admission policy. Instead, the university has to enroll all the students which apply, irrespective of their ability at the entrance. In this sense, our model more specifically applies to university systems where the university have the mission of mass teaching and cannot control the ability of the enrolled students through exams and/or tuition fees.

For a given number of departments N, depending on the internal financing rule γ, the university achieves an output combination (n, R) equals to $(t^*, r^*(\bar{s}t^*)^{1-h})$. Proposition (2.2) tells us that when γ increases, n decreases. There are less students and therefore less funds for research. But it does not necessarily mean that the research output decreases because a decrease in research fund is compensated by an increase in the research effort (at least in those parameter space where r^* increases with γ). Direct computations indicate the following:

Proposition 2.3 *The research output increases in γ for* $\gamma \in [0, \mathrm{Min}[1, \tilde{\gamma}]]$ where $\tilde{\gamma} = \dfrac{N-1}{N}\,\dfrac{1-h+h^2}{5-9h+4h^2}$

Accordingly, our model leads to the identification of a production possibility frontier for the university

We are now in position to represent the production frontier of a university with N departments. The following figure represents the combination of output that a university can achieve as a function of its internal financing rule γ. Notice that we restrict attention here to that part of the frontier which is decreasing in the $n-R$ space, i.e. that part along which there is a real trade-off between research and teaching.



Thus, depending on their preferences for the two-dimensions of the output, the universities will choose different financing rules. For example, a university that value teaching a lot and emphasizes less research will select point A, while a university that is more interested in research and less in teaching will choose point B.

3. Final remarks

This paper has shown that the allocation of the research budget to departments affects the academics' incentives to exert teaching and research efforts. Incentives, in turn, affect the effort levels and finally the output. Depending on their preferences for the research achievement and for the number of students the universities will choose different financing rules. A university which is more focused on attracting a lot of students will choose a low value of γ (i.e. a research budget based mainly on the number of students) while a university more focused on research will choose a higher value of γ to create more competition for research funds and to stimulate the research efforts. The choice of internal financing rules thus reflects the balance between teaching and research in the objective function, or more precisely in the preferences, of the university. In this respect, our results complements those of Beath *et al.* (2005) who study the teaching-research trade-off when universities possibly face different financing systems.

References

BEATH J., R. OWEN, J. PAYAGO-THEOTOKY, D. ULPH (2003), "Optimal Incentives for Income Generation in Universities: the Rule of Thumb for the Compton Tax", *International Journal of Industrial Organization*, 21, pp. 1301-1322.

BEATH J., J. PAYAGO-THEOTOKY, D. ULPH (2005), "University funding systems and their Impact on Research and Teaching: a General Framework", Discussion paper 2005-2, Economics Department, Loughborough University.

COUPÉ T. (2001), "Should University be Conglomerate", In: M. Dewatripont, F. Thys-Clément and L. Wilkin (Eds.), *The Strategic Analysis of Universities: Microeconomics and Management Perspectives*, Editions de l'Université de Bruxelles, Brussels.

DE FRAJA G. and E. IOSSA (2002), "Competition among Universities and the Emergence of the Elite Institution", *Bulletin of Economic Research*, 54, pp. 275-294.

DEL REY E. (2001), "Teaching versus Research: a Model of State University Competition", *Journal of Urban Economics*, 49, pp. 356-373

GAUTIER A. and X. WAUTHY (2007), "Teaching versus Research: a Multi-Tasking Approach to Multi-Department Universities", *European Economic Review*, 51, pp. 273-295.

NEARY P., J. MIRRLEES and J. TIROLE (2003), "Evaluating Economics Research in Europe: an Introduction", *Journal of the European Economic Association*, 1, pp. 1239-1249.

SHATTOCK M. (2002), "Evaluating University Success", In: M. Dewatripont, F. Thys-Clément and L. Wilkin (Eds.), *European Universities: Change and Convergence*, Editions de l'Université de Bruxelles, Brussels.

University competition: Symmetric or asymmetric quality choices?

Eve VANHAECHT and Wilfried PAUWELS [1]

Summary

In this paper we model competition between two publicly financed and identical universities deciding on the quality of their teaching. The education offered by the two universities is differentiated horizontally and vertically. If horizontal differentiation dominates, the Nash equilibrium is symmetric, and the two universities offer the same quality levels. If vertical differentiation dominates, the Nash equilibrium is asymmetric, and the high quality university attracts the better students. Symmetric and asymmetric equilibria may also coexist. The three driving forces behind these results are: a single crossing condition for the utility of the students, the peer group effect, and the students' mobility costs. We also compare the monopoly and the duopoly case, and find that a shift from monopoly to duopoly increases teaching quality.

1. Introduction

It is widely recognized that in many European countries universities provide teaching of a rather uniform quality level, while US universities typically offer teaching of varying quality levels. Moreover, European students are traditionally considered less mobile than US students. One of the conclusions of the empirical study of Sá, Florax and Rietveld (2004), for instance, is that in the Netherlands a situation of uniform quality of universities goes hand in hand with immobile students [2]. In this paper we theoretically investigate the relationship between the quality

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[2] Sá, Florax and Rietveld (2004) investigated the determinants of university entrance for Dutch high school graduates. At the time of the study, Dutch universities were publicly funded, tuition fees were centrally determined and uniform across institutions. Rationing of supply (i.e. setting admission criteria) was allowed but non-existent. The authors found that the choice of potential students is negatively affected by the distance between a student's home and the location of the university. Surprisingly, the quality of teaching does not seem to play a significant role in the students' choice behavior. The authors suggest that this can be explained by the fact that the quality differences between Dutch universities are relatively small.

choices of the universities and the mobility cost faced by students in the context of university competition.

The aim of this paper is to study the interplay between vertical and horizontal differentiation of publicly funded universities. We develop a game in which two universities decide on the quality of their teaching while having a fixed physical location. Their payoff is specified as a weighted sum of teaching quality and available research funds. Each student is characterized by a geographical location, and by a level of innate ability. Given these two characteristics, students rank the two universities in order of their preference. This ranking depends on two critical considerations. First, there are mobility costs. Each student is located at a certain distance from each university, implying a mobility cost for each university. Students with different locations face different mobility costs. These costs give rise to horizontal differentiation between the universities. Secondly, universities can offer study programs of different quality levels. This gives rise to vertical product differentiation.

For our results it is important to consider domination of one type of differentiation by the other. If all students living sufficiently close to a particular university, prefer that university to the other, for all levels of ability, we say that horizontal differentiation dominates vertical differentiation (i.e. there is *horizontal dominance*). Conversely, if all students with a sufficiently high (low) ability level prefer the high (low) quality university, for any given physical location, then vertical differentiation dominates (i.e. there is *vertical dominance*).

We show that each of the two types of domination gives rise to a different type of equilibrium. If horizontal differentiation dominates, the equilibrium quality levels offered by the two universities will be the same. The Nash equilibrium is symmetric. If, on the other hand, vertical product differentiation dominates, equilibria occur in which the two universities offer different quality levels. The high quality university attracts the better students. The Nash equilibrium is asymmetric. This is remarkable since the two universities are ex ante identical.

This result is consistent with the literature dealing with horizontal and vertical differentiation within the field of industrial organization theory (see, e.g., Anderson, de Palma and Thisse, 1992, and Irmen and Thisse, 1996). A basic result in this literature is that minimal differentiation is possible in one dimension only if differentiation is sufficiently large in the other. Applied to our model, this means that minimal differentiation in quality (symmetric quality levels) is only possible when mobility costs are sufficiently large (when there is horizontal dominance).

Depending on the exact parameter values the following equilibrium configurations occur: one symmetric equilibrium, two asymmetric equilibria, and one symmetric together with two asymmetric equilibria.

There are three basic characteristics that drive our results. First, preferences of the students have to satisfy a single crossing property. In particular, a student's effort required to obtain a degree of a certain quality decreases as the student's ability increases, and, for a given level of ability, a student's required effort increases as quality increases. This seems to be a very reasonable property of any student's preferences. In the absence of this property, there can be no vertical product differentiation in equilibrium. Secondly, there is the peer group effect. The larger the average ability level of the student body, the smaller the teaching cost required to realize a degree of a given quality level. Without this effect, there does not exist an equilibrium in which the universities are vertically differentiated. Finally, as already noted, there are mobility costs. If students do not care about the geographical location of the universities because mobility costs are zero, Betrand competition leads the universities to a corner solution in which both of them devote all funds to teaching. If one considers students' mobility costs as a public policy variable [3], we show at the end of this paper that changes in this variable clearly affect competition between the two universities and the resulting teaching quality.

In the paper we will analyze the monopoly as well as the duopoly case. We show that an increase in competition – a move from monopoly to duopoly – always raises the average quality level of teaching.

The literature on quality competition between publicly funded universities is very limited. A first important contribution was made by Del Rey (2001). In her model universities compete in two stages: first they select a quality level and afterwards they set an admission standard [4]. There is no vertical product differentiation in equilibrium. Only symmetric Nash equilibria occur. We extend Del Rey's (2001) model by introducing the single crossing condition already mentioned, and by using a different specification for a university's teaching cost function. Moreover, for simplicity, we dropped the possibility for universities to select an admission standard, but we know from previous work that this does not matter for our main conclusions [5].

A second important reference is De Fraja and Iossa (2002). One of their main results is that asymmetric equilibria in admission standards (as an indicator of quality) occur, provided mobility costs are not too high. In our paper we assume universities compete in quality, and this quality is positively related with the average ability level of the students enrolling in a university. Similar to De Fraja and Iossa (2002), we find a link between the asymmetry of the equilibrium and the height of the mobility costs. The differences between the paper of De Fraja and Iossa (2002) and this paper can be summarized as follows. First, we link the symmetry or asymmetry of the equilibria to the properties of horizontal and vertical dominance, and not only to mobility costs. Second, as opposed to De Fraja and Iossa (2002) we also show that a symmetric equilibrium and two asymmetric equilibria can coexist. Third, in our model we explicitly include a peer group effect in the teaching cost function of a university: teaching higher ability students requires less investments to reach a certain quality compared to lower ability students. We show that this effect clearly influences competition. Fourth, De Fraja and Iossa (2002) assume all students benefit from an increase in teaching quality, so that all students prefer to enrol in the highest quality university. Because of asymmetry in the admission standards, however, only the highest ability students are admitted at the most selective university. In our model, however, low ability students loose from an increase in

[3] A regulator can lower mobility costs by providing free public transport for students.

[4] This is the minimal level of ability required for admission at the university.

[5] A previous version of the paper including admission standards can be obtained from the authors on request.

quality because it requires too much effort. Consequently, if there is asymmetry in quality, students sort themselves over the two universities according to their ability level and their physical location. Finally, we find that the role of the mobility costs is more important and more complex than suggested by De Fraja and Iossa (2002). Apart from leading to symmetry or asymmetry, the level of mobility costs affects the equilibrium quality levels themselves. Moreover, if there are no mobility costs, the race in quality between the two universities leads to the disappearance of research activities: all available funds will be devoted to teaching.

Finally, a third important reference is Kemnitz (2005) who investigates the impact of university finance reforms on teaching quality competition in a setting similar to Del Rey (2001). The differences with Del Rey (2001) are that he does not include mobility costs, and that teaching costs are assumed to be convex in quality. Similar to De Fraja and Iossa (2002) he assumes all students gain from an increase in teaching quality. He makes the comparison with the social optimum (i.e. the quality levels which maximize the students' as well as the universities' surplus).

Next to papers on quality competition between publicly funded universities, other important papers have to be mentioned. Some papers are concerned with profit maximizing universities (or schools) competing in tuition fees (see, e.g., Rothshild and White, 1995, and Epple and Romano, 1998), with universities who have to decide which new programs they launch (Del Rey and Wauthy, 2006), with competition between non-profit and for-profit universities (Del Rey and Romero, 2004), or with quality differentiated universities having to decide on the workload of their bridging programs [6] (Vanhaecht, 2005).

The structure of the paper is as follows. In Section 2 we describe the behavior of the students and the universities. Section 3 analyzes the case of a monopolistic university. In Section 4 we solve the duopoly case. Section 5 concludes.

2. The model

In this section we describe the basic ingredients of the model. We first specify the behavior of the students. We then analyze the decisions of the universities.

A. *The students*

Consider a unit mass of students. Students are characterized by their physical location x, and by their innate ability (or talent) level a. These two characteristics are assumed to be uniformly and independently distributed on $[0,1] \times [0,1]$. We want to describe how a student with characteristics (x, a) chooses between two universities. The two universities differ in their fixed physical location, and they can choose the quality of their degrees. University 1 is physically located at $x = 0$, and university 2 at $x = 1$. Moreover, university 1 offers a degree of quality level q_1, while university 2 offers a degree of quality level q_2. We assume that a student with ability a and physically located at a distance x from university 1 and a distance $(1 - x)$ from university 2 enjoys the following utility levels from attending university 1 and 2, respectively,

[6] Bridging programs are defined as the extra courses students have to attend when switching from one university's bachelor's program to another university's master's program.

$$u_1 = \xi + q_1 - \alpha(1 - a)q_1 - cx \tag{1}$$

$$u_2 = \xi + q_2 - \alpha(1 - a)q_2 - c(1 - x) \tag{2}$$

First, simply attending a university augments the student's utility with the constant ξ. We assume that ξ is high enough, so that the student always prefers attending a university to not attending. In other words, we assume that there is no binding participation constraint for students [7]. Second, a student incurs a mobility cost which is taken to be proportional to the distance between her own physical location and that of the university at which she enrolls. A student located at a distance x from university 1 faces a mobility cost of cx when attending university 1, and of $c(1 - x)$ when attending university 2. Third, the quality of the degree offered affects a student's utility in two different ways. On the one hand, a student's future wage premium due to university education is increasing in the quality level of the university chosen. On the other hand, obtaining a degree at a higher quality university requires a higher investment of effort from the student. The effect of this effort cost is given by $\alpha(1 - a)q_1$, where α is a positive number. The required effort cost decreases with the ability a of the student [8]. Remark that the utility levels (1) and (2) imply the following *single crossing property*

$$\frac{\partial^2 u_i}{\partial q_i \partial a} = \alpha > 0. \tag{3}$$

See Mirrlees (1971) and Spence (1973). It means that the net gain from an increase in quality is always higher for a higher ability student. Or, equivalently, the marginal effort cost for a degree of a given quality is decreasing in a student's ability level [9].

From now on we assume that $\alpha = 2$. Hence, (1) and (2) reduce to

$$u_1 = \xi + (2a - 1)q_1 - cx \tag{4}$$

$$u_2 = \xi + (2a - 1)q_2 - c(1 - x) \tag{5}$$

The reasons for doing this can be summarized as follows [10]. First, we want to assure that the students with an ability above the average $\frac{1}{2}$ benefit from an increase in quality, while it requires too much effort from the students with an ability below the average,

$$\frac{\partial u_i}{\partial q_i} = 2a - 1 > 0 \Leftrightarrow a > \frac{1}{2}. \tag{6}$$

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[7] Only students who pass the *German Abitur*, for instance, are allowed to enter university education in Germany. The standards for this exam are set by the regulator. Hence, total market demand is not really affected by actions of individual universities.

[8] Hence, effort is *not chosen* by the student herself. The student chooses a university with a certain quality level and this implies the required effort.

[9] If α equals zero (no single crossing) the utility levels reduce to the ones used by Del Rey (2001), and then we know that there is no asymmetric solution in quality.

[10] Notes on other values of α can be obtained from the authors. In this paper, however, we do not comment on what happens if $\alpha \neq 2$. The discussion would be too lengthy and confusing. Moreover, a wider range of different cases would have to be investigated.

Figure 1 The relation between a student's utility and her ability when $c = 0$ and $q_1 > q_2$.

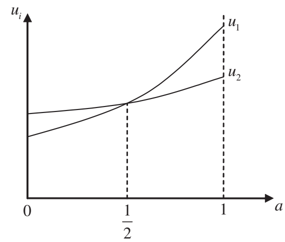


Figure 1 illustrates the relation between a student's ability and her utility level when c equals *0* and q_1 exceeds q_2. (For positive values of c we would have to work in three dimensions.) Second, setting $\alpha = 2$ will imply that either vertical or horizontal differentiation between the two universities dominates. For other values of α there will always be cases in which neither of the two types of differentiation dominates. This concept of domination will become clear in the next paragraph. Finally, assuming that $\alpha = 2$, will fix both universities' market shares equal to $\frac{1}{2}$, independent of the quality they provide to their students. The average ability of the students attracted to the universities will still depend on the quality chosen. Consequently, universities can not compete in quantity (student numbers), and we can really focus on *qualit*y competition. Again, this will be clarified in the next paragraph.

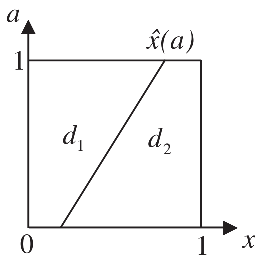
We now analyze the students' choices between the two universities. The students who are indifferent between studying at university 1 and 2 mark the boundary between the two universities' markets. Setting u_1 equal to u_2 and solving for x yields the market boundary, denoted $\hat{x}(a)$

$$\hat{x}(a) = \frac{(2a-1)(q_1 - q_2) + c}{2c}. \tag{7}$$

Students with characteristics (x, a) such that $x \leq \hat{x}(a)$, prefer university 1. Students for whom $x \geq \hat{x}(a)$ prefer university 2. For a given quality difference $q_1 - q_2$, equation (7) defines a straight line in the (x, a)-space. Students to the left of this line prefer university 1. The number of these students is denoted by d_1, the demand for university 1. Students to the right of this line prefer university 2. The number of these students is denoted d_2, the demand for university 2. Since we assume that students always prefer attending a university to not attending one, it follows that $d_1 + d_2 = 1$. Whenever the universities offer different quality levels, we will call university 1 the high and university 2 the low quality university, $q_1 - q_2 \geq 0$. Consequently, the market boundary given in (7) has a positive slope.

The distance between a student's physical location and the location of a university differentiates the two universities horizontally. The quality difference between the two universities differentiates them vertically. Comparable to Anderson, De

Figure 2 Horizontal dominance



Palma and Thisse (1992) and Degryse (1996) we distinguish between two possible cases: *horizontal and vertical dominance*.

On the one hand, if $q_1 - q_2 \geq c$, we say that there is horizontal dominance: both universities attract a positive market share for all ability levels. The slope of the market boundary is then smaller than one ($\frac{\partial \hat{x}(a)}{\partial a} \leq 1$). See Figure 2. The demands for university 1 and 2 become

$$d_1 = \int_0^1 \hat{x}(a)da \text{ and } d_2 = \int_0^1 (1 - \hat{x}(a))da. \tag{8}$$

The average ability levels of the students attracted to university 1 and 2 equal

$$\overline{a}_1 = \frac{1}{d_1}\left[\int_0^1 a(\hat{x}(a))da\right] \text{ and } \overline{a}_2 = \frac{1}{d_2}\left[\int_0^1 a(1 - \hat{x}(a))da\right]. \tag{9}$$

Remark that as long as $q_1 - q_2 \leq$ c it does not matter whether $q_1 \geq q_2$ or vice versa. The expressions given in (8) and (9) do not change.

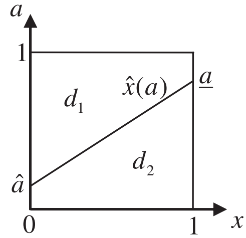
On the other hand, if the inequality $q_1 - q_2 \geq$ c holds, we say that there is vertical dominance: the high quality university 1 obtains the entire market for high ability students, while the low quality university 2 attracts all low ability students. The slope of the market boundary is larger than one ($\frac{\partial \hat{x}(a)}{\partial a} \geq 1$). See Figure 3. In this figure we have

$$\hat{a} = \frac{1}{2} - \frac{c}{2(q_1 - q_2)} \text{ and } \underline{a} = \frac{1}{2} + \frac{c}{2(q_1 - q_2)}. \tag{10}$$

The demands for university 1 and 2 are now given by

$$d_1 = \int_{\hat{a}}^{\underline{a}} \hat{x}(a)da + \int_{\underline{a}}^{1} da \text{ and } d_2 = \int_0^{\hat{a}} da + \int_{\hat{a}}^{\underline{a}} (1 - \hat{x}(a))da. \tag{11}$$

Figure 3 Vertical dominance



The average ability levels of the students attracted to university 1 and 2 become

$$\overline{a}_1 = \frac{1}{d_1}\left[\int_{\hat{a}}^{\underline{a}} a\hat{x}\,(a)\,da + \int_{\underline{a}}^{1} ada\right] \text{ and } \overline{a}_2 = \frac{1}{d_2}\left[\int_{0}^{\hat{a}} ada + \int_{\hat{a}}^{\underline{a}} a(1-\hat{x}\,(a))da\right]. \quad (12)$$

Remark that now it does matter whether $q_1 \geq q_2$ or vice versa. As we assumed that $q_1 - q_2 \geq$ c, the expressions given in (11) and (12) only apply to the case where $q_1 \geq q_2$.

Using (7)-(12), we find that, for all values of $q_1 - q_2 \geq 0$ and of c,

$$d_1 = d_2 = \frac{1}{2}. \quad (13)$$

It follows that, independent of the quality difference and of the mobility cost, both universities' demands always equal one half of the total student population. Remember that this results from the fact that we set α equal to *2*. Furthermore, although both universities attract exactly the same number of students, it is clear from Figure 2 and Figure 3 that a *university who provides higher quality teaching always attracts a student body with a higher average ability level*. Consequently, the universities can not compete in quantity, only in quality.

The case $q_1 - q_2 \leq 0$ can be treated very similarly. The market boundary (7) will then have a negative slope. Expressions for both universities' demands can be obtained by changing the subindexes 1 and 2.

B. The universities

In this section we first specify a university's cost function of teaching. Then we describe the budget constraint. Finally, we introduce the payoff function of a university.

The teaching cost T_i of university i is modelled as follows

$$T_i = (1 - \eta\,\overline{a}_i)q_i^2 \quad (14)$$

with $0 < \eta < 1$. A university's teaching cost is decreasing in the average ability $\bar{a}_i$ of its enrolled students: the higher the average ability of the students, the smaller the expenses required to attain a given quality of education. The strength of this effect depends on the parameter η. The teaching cost function given in (14) in fact expresses that students are inputs in the production process of their own human capital (Rothshild and White, 1995). We assume that the parameter η is always strictly between zero and one. We will see later on that our results are largely driven by the presence of this *peer group effect*[11]. In other words, we need $\eta > 0$ to have an asymmetric equilibrium in quality. Furthermore, a university's teaching cost increases with the quality q_i provided. Remark that we assume that marginal costs are increasing in quality.

The budget constraint of a university is kept very simple. A university receives a lump sum budget F from the regulator. These funds can be used by a university to finance its teaching activities or to spend on research. Research funds are denoted by R_i. The budget constraint is given by

$$F = T_i + R_i. \tag{15}$$

Remember that above we derived that $d_i = \frac{1}{2}$ independent of the quality provided by the university. Hence, making the funding dependent on a university's number of enrolments would not change our results. Studying the effects of different funding mechanisms, as done in Kemnitz (2005), lies outside the scope of this paper.

The specification of a public university's objective function is not straightforward. In line with Del Rey (2001), De Fraja and Iossa (2002) and Kemnitz (2005) we assume that universities are interested in the prestige of their institution. This prestige depends on the number of enrolled students, on the quality of the university's teaching, and on the expenditures on research. Since in our model the number of students enrolling in a university is fixed, we use the following specification

$$U_i = q_i + \gamma R_i. \tag{16}$$

The term q_i measures the teaching quality of the university, and R_i represents the funds available for research. The weight attached to the latter equals γ. From (14) and (15) it follows that

$$R_i = F - (1 - \eta\, \overline{a}_i) q_i^2. \tag{17}$$

The university's payoff function can finally be written as

$$U_i(q_1, q_2) = q_i + \gamma \left[F - (1 - \eta \overline{a}_i) q_i^2\right]. \tag{18}$$

A clear weakness of this specification is that the research output of a university is measured by the size of the research budget. This neglects the quality aspect of the research. Moreover, there may be economies of scope between teaching and

[11] We are aware of the fact that the peer group effect in education is often defined as: students gaining from being among abler students. This would mean that the utility of a student is increasing in the average ability of her fellow students. This is not included in the students' utilities given in (1) and (2). Similar to Del Rey (2001) and Kemnitz (2005) we only include a peer group effect in a university's teaching cost function.

research. A high quality of teaching will also benefit the quality of research, and vice versa [12].

The complete game can now be specified as follows. The universities simultaneously decide on their quality levels q_1 and q_2. Students observe these levels, and decide to enrol in one of the two universities. This was shown in Figure 2 and Figure 3. Knowing q_i and $\bar{a}_i$, each university calculates its teaching cost T_i. Subtracting this cost from the total government subsidy F yields the available research funds R_i.

Before solving the game between the two universities we first study the case in which one university has a monopoly. This is an important benchmark case.

3. The monopoly case

In this section we consider the case where there is only one university. As we assumed that all students always want to attend a university, the demand for the single university equals the total student population, $d_m = 1$, independent of the quality of its teaching. The average ability level $\bar{a}_m$ equals $\frac{1}{2}$ independent of the monopolist's quality choice. The monopolist's payoff function can be written as

$$U_m\,(q_m) = q_m + \gamma\left[F - (1 - \frac{\eta}{2})q_m^2\right]. \tag{19}$$

The university maximizes this function with respect to q_m. The first order condition requires that $1 - \gamma\,(1 - \frac{\eta}{2})2q_m = 0$. Hence, the quality choice which satisfies this becomes $q_m = \frac{1}{\gamma(2-\eta)}$. The second order condition $-\,2\gamma\,(1 - \frac{\eta}{2}) < 0$, is satisfied. The following theorem easily follows.

Theorem 1 *A monopolistic university's optimal quality level is given by*

$$q_m^* = \frac{1}{\gamma(2 - \eta)}.$$

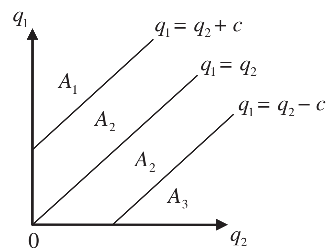
The following comparative statics results easily follow from Theorem 1. First, the larger the peer group effect η, the higher the monopolist's quality choice. This stems from the fact that for a given amount of funds spent on teaching, a higher value of η allows the university to provide higher quality teaching. This implies that more funds will be spent on teaching and less on research when η increases. In the absence of the peer group effect ($\eta = 0$) the monopolist's quality choice equals $\frac{1}{2\gamma}$. Second, the higher the monopolist's preference for research γ, the lower its quality choice, the less it spends on teaching and the higher the size of the research funds. In the limiting case, a pure research oriented university devotes all funds to research and offers education of zero quality, $\lim_{\gamma\to\infty} q_m^* = 0$ so that teaching costs are zero.

[12] In the current context, economies of scope exist if there are cost efficiencies to be gained by jointly producing teaching and research output, rather than producing each of them separately. Empirical research on economies of scope between undergraduate teaching, graduate teaching and research can be found in e.g. Hashimoto and Cohn (1997), Johnes (1997), and Koshal and Koshal (1999).

4. The duopoly case

In this section we solve the duopoly game. In this game both universities simultaneously decide on quality levels q_1 and q_2. Comparing these quality levels the students sort themselves over the two universities. Depending on the parameter values, the following Nash equilibrium configurations can appear: (I) one symmetric equilibrium in which the quality levels of the two universities are equal and funds are devoted to both teaching and research, (II) two asymmetric equilibria in which one university provides higher quality education than the other and funds are devoted to both teaching and research, (III) one symmetric and two asymmetric equilibria and funds are devoted to both teaching and research, and (IV) a symmetric equilibrium in which all funds are devoted to teaching. We analyze each of these possibilities.

Figure 4 Important areas in the (q_1, q_2) space



Before doing so, we have to make an important technical remark. When solving this game, we always have to restrict ourselves to one of the two cases defined above: horizontal ($q_1 - q_2 \leq c$) or vertical dominance ($q_1 - q_2 \geq c$). In other words, we restrict ourselves to a certain area in the $(q_1 - q_2)$ space. See Figure 4. From the previous section we know that for each case there is a specific way in which $\bar{a}_i$ depends on q_1 and q_2. See (9) and (12). Using this dependence, we investigate whether there is an equilibrium in quality levels. Ex post we have to check whether this equilibrium actually lies within the area considered Moreover, even if this is the case, it is not impossible that, given the rival's strategy, it pays for a university to choose a quality level in a different area, so that the equilibrium is local and not global.

A. *Horizontal dominance: symmetric quality choices*

In this section we investigate the case of *horizontal dominance*. This means that we assume that the quality difference between the two universities is smaller than the mobility cost faced by the students: $q_1 - q_2 \leq c$ (area A_2 in the (q_1, q_2) space). We know that the average abilities of both universities' student bodies are then given in (9). We insert these expressions into the payoff functions (18) of the two universities. We maximize each payoff function with respect to the quality level of that university.

The resulting system of first order conditions has four solutions. However, only the following *symmetric* solution

$$q_1^S = q_2^S = \frac{3c\gamma(2-\eta) - \sqrt{3}\sqrt{c\gamma(3c\gamma(-2+\eta)^2 - 2\eta)}}{\gamma\eta} \tag{20}$$

satisfies all conditions for a Nash equilibrium for certain parameter values. First, the solution given in (20) is feasible if and only if

$$c > \frac{2\eta}{3\gamma(-2+\eta)^2}. \tag{21}$$

Second, second order conditions are satisfied if and only if

$$c > \frac{8\eta}{9\gamma(-2+\eta)^2}. \tag{22}$$

Third, let us denote the reaction function of university i by R_i. Local stability of the equilibrium then requires that

$$1 - \left|\frac{\partial R_1(q_2^S)}{\partial q_2}\right| \left|\frac{\partial R_2(q_1^S)}{\partial q_1}\right| > 0. \tag{23}$$

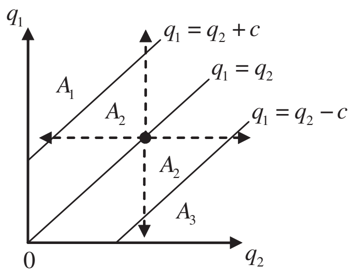
This condition is satisfied if and only if

$$c > \frac{6\eta}{5\gamma(-2+\eta)^2}. \tag{24}$$

Remark that satisfaction of condition (24) implies satisfaction of conditions (21) and (22). Finally, at the beginning of this subsection we assumed that both universities' quality choices are situated within area A_2 in the (q_1, q_2) space. See Figure 4. We are sure that, within this area, (20) gives both universities' best strategy. Ex post we have to check whether none of the universities has an incentive to use a strategy outside area A_2. First, given that $q_2 = q_2^S$, we have to investigate whether it pays for university 1 to increase its quality to a quality level $q_2^S + c + \varepsilon$ in area A_1. This will not be interesting for university 1 as long as $U_1(q_1^S, q_2^S) \geq U_1(q_2^S + c + \varepsilon, q_2^S)$. Second, given that $q_2 = q_2^S$, we have to investigate whether it pays for university 1 to decrease its quality to a quality level $q_2^S - c - \varepsilon$ in area A_3. This will not be the case if and only if $U_1(q_1^S, q_2^S) \geq U_1(q_2^S - c - \varepsilon, q_2^S)$. Two similar deviations exist for university 2. See Figure 5. Unfortunately, we can not give exact restrictions on the parameter values which do not give incentives for both universities to deviate from the equilibrium in (20). Intuitively, however, it is clear that for larger values of c deviating to $q_i^S + c + \varepsilon$ or $q_i^S - c - \varepsilon$ requires a larger jump in quality. Since teaching costs are increasing and convex in quality this jump will be too costly for very large values of c. In the next subsection we show numerically that for some parameter values (20) is a stable and global Nash equilibrium, and that no university deviates from it.

Now consider Theorem 2.

Figure 5 Deviations from the symmetric equilibrium



Theorem 2 *Assume that (24) holds. Then, there exists a symmetric, stable and local Nash equilibrium given by*

$$q_1^S = q_2^S = \frac{3c\gamma(2-\eta) - \sqrt{3}\sqrt{c\gamma(3c\gamma(-2+\eta)^2 - 2\eta)}}{\gamma\eta}.$$

In the next subsection we show that for certain parameter values this equilibrium is also *global*. From Theorem 2 we conclude that a sufficiently high value of the mobility cost faced by students induces both universities to offer the same quality to their students.

Two interesting properties of this equilibrium are worth mentioning. First, within area A_2 both universities' reaction functions are downward sloping. See Figure 6. This follows from

$$\frac{\partial^2 U_1}{\partial q_1 \partial q_2} = \frac{-q_1\gamma\eta}{6c} < 0 \text{ and } \frac{\partial^2 U_2}{\partial q_2 \partial q_1} = \frac{-q_2\gamma\eta}{6c} < 0. \tag{25}$$

Hence, in this equilibrium the quality choices of the two universities are *strategic substitutes*: when university 1 raises its quality choice, university 2 will react by lowering its quality choice, and vice versa. Second, the equilibrium is symmetric, not only in the sense that both universities select the same quality level $q_1^S = q_2^S$, but also in the sense that they attract a student body with the same average ability $\overline{a}_1^S = \overline{a}_2^S = \frac{1}{2}$, spend the same amount on teaching $T_1^S = T_2^S$, spend the same amount on research $R_1^S = R_2^S$ and hence have the same payoff $U_1^S = U_2^S$. See Figure 7.

Figure 6 Reaction functions: symmetric equilibrium

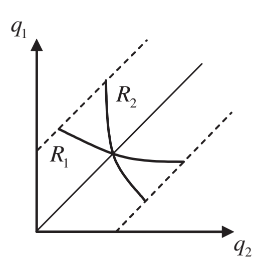
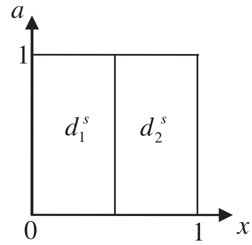


Figure 7 Division of students in the symmetric equilibrium



Let us examine some comparative statics. First, we find that an increase in the peer group effect η raises the equilibrium quality level. The reasoning is similar to the one we gave for the monopolist. From (20) it is not immediately clear what happens when we neglect this peer group effect ($\eta = 0$). It is easy to check, however, that in that case both universities provide education with a quality level equal to $\frac{1}{2\gamma}$ [13]. Second, an increase in the marginal utility of research γ decreases the equilibrium quality level. Moreover, if both universities are entirely focused on maximizing research funds, both devote all funds to research and offer education of zero quality, $\lim_{\gamma \to \infty} q^s = 0$, so that teaching costs are zero.

The role of the mobility cost parameter at the symmetric equilibrium

From theorem 2 it follows that an increase in the mobility cost c leads to a reduction in the symmetric quality level

$$\frac{\partial q_i^S}{\partial c} < 0 \qquad i = 1, 2. \tag{26}$$

This stems from the fact that a change in the mobility cost c influences the average ability of the student body attracted to each university. We find that

$$\frac{\partial^2 \bar{a}_i}{\partial q_i \partial c} = \frac{-1}{6c^2} < 0 \qquad i = 1, 2. \tag{27}$$

This means that *as the mobility cost increases, the positive effect of an increase in quality on the average ability of a university's student body (*$\frac{\partial \bar{a}_i}{\partial q_i} > 0$*) becomes smaller and smaller*. Consequently, a university will lower its quality choice as the mobility cost increases. In the limiting case where the mobility costs go to infinity, the symmetric quality level for the duopoly case reduces to the quality choice of a monopolistic university, as given in Theorem 1 [14]. Hence, the quality offered by the duopolists is always larger than or equal to the quality offered by a monopolistic university, $q^S \geq q_m^*$.

---

[13] Maximizing $q_i + \gamma\,[F - q_i^2]$ with respect to q_i yields $q_i = \frac{1}{2\gamma}$.

[14] If the mobility costs go to infinity, students simply attend the university closest to their own physical location, $\lim_{c \to \infty} (\hat{x}(a)) = \frac{1}{2}$.

B. *Vertical dominance: asymmetric quality choices*

In this subsection we investigate the case of *vertical dominance*. In other words, we assume that the quality difference between the two universities exceeds the mobility cost faced by the students so that on Figure 4 we are in area A_1. The average abilities of both universities' student bodies can therefore be found in (12). We insert these expressions into the payoff functions of the universities. Maximizing each payoff function with respect to the quality level of that university yields two first order conditions. This system of equations has one *asymmetric* solution with positive quality choices [15],

$$q_1^A = \frac{K}{12\gamma\eta^2(4-3\eta)},\quad q_2^A = \frac{K}{12\gamma\eta^2(4-\eta)} \tag{28}$$

with $K = 12\,\eta^2 + \sqrt{6}\sqrt{\eta^2(24\eta^2 + c^2\gamma^2(16-16\eta+3\eta^2)^2)}$. The following conditions have to be satisfied for (28) to be a Nash equilibrium. First, satisfaction of the second order conditions requires that

$$c < \frac{8\sqrt{4-\frac{7\eta}{3}}\,\eta^{3/2}}{\gamma\sqrt{(4-3\eta)^4(-4+\eta)^2}}. \tag{29}$$

Second, let us denote the reaction function of university i by R_i. Again, local stability of the equilibrium then requires that (23) is satisfied. Unfortunately, we can not translate this requirement into an explicit condition on the parameter values. In the numerical examples of the next section we do check for stability of the asymmetric solution. Third, initially we assumed that $q_1 - q_2 \geq c$. This requires satisfaction of the following condition

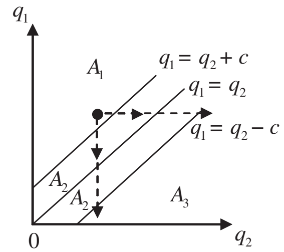
$$c < \frac{24\eta}{5\gamma(-4+\eta)(-4+3\eta)}. \tag{30}$$

Finally, the quality choices given in (28) concern both universities' best strategy within area A_1. Again, we have to investigate whether, given its rival's strategy, none of the universities has an incentive to select a quality level outside area A_1. Does it pay for university 1 to lower its quality choice to $q_2^A + c - \varepsilon$ (area A_2) or to $q_2^A - c - \varepsilon$ (area A_3)? Or does it pay for university 2 to increase its quality choice to $q_1^A - c + \varepsilon$ (area A_2) or to $q_1^A + c + \varepsilon$ (area A_3)? See Figure 8.

Unfortunately, we cannot give exact restrictions on the parameter values implying that no university has an incentive to deviate from (28). In the appendix we prove that in absence of mobility costs ($c = 0$) both universities want to attract the ablest students by just leapfrogging their rivals quality choice (i.e. $q_i = q_j + \varepsilon$). Hence, the two universities engage in a kind of Bertrand competition which results in the following symmetric *corner* solution $q_1 = q_2 = q^{\max} = \frac{\sqrt{F}}{\sqrt{1-\frac{\eta}{2}}}$. In this corner solution both universities devote all funds to teaching activities, and neglect research. The same argument applies to very small values of c.

[15] We dropped an asymmetric solution with negative quality choices.

Figure 8 Possible deviations from the asymmetric equilibrium



In general, we conclude that for intermediate values of c the quality competition between the two universities results in an asymmetric Nash equilibrium as given in (28). Now consider Theorem 3.

Theorem 3 *Assume conditions (29) and (30) hold. Then there exists an asymmetric and local Nash equilibrium in which*

$$q_1^A = \frac{K}{12\gamma\eta^2(4-3\eta)},\ q_2^A = \frac{K}{12\gamma\eta^2(4-\eta)}$$

The numerical calculations in the next section show that for a reasonable set of parameter values this asymmetric Nash equilibrium is also global and stable. Of course, since the two universities are identical it must be that there also exists a similar asymmetric equilibrium in which university 2 offers a higher quality level than university 1

$$q_1^A = \frac{K}{12\gamma\eta^2(4-\eta)},\ q_2^A = \frac{K}{12\gamma\eta^2(4-3\eta)}. \tag{31}$$

Let us discuss two interesting features of the equilibrium given in Theorem 3. First, we find that within area A_1 the reaction function of the high quality university 1 is upward sloping while the one of the low quality university 2 is downward sloping,

$$\frac{\partial^2 U_1}{\partial q_1 \partial q_2} = \frac{c^2 q_1(q_1+2q_2)\gamma\eta}{12(q_1-q_2)^4} > 0 \text{ and } \frac{\partial^2 U_2}{\partial q_2 \partial q_1} = -\frac{c^2 q_2(q_2+2q_1)\gamma\eta}{12(q_1-q_2)^4} < 0. \tag{32}$$

This means that an increase in q_2 induces university 1 to increase q_1, while an increase in q_1 induces university 2 to decrease q_2. See Figure 9 [16]. Second, at the equilibrium described in Theorem 4 university 1 offers a higher quality level, and hence it attracts a student body with a higher average ability compared to university 2. See Figure 10. Because of the higher average ability level of university 1's student body it pays more

[16] In this Figure we see that, for certain parameter values, the reaction functions are not continuous. As q_2 starts to increase from 0, university 1 reacts by increasing q_1.However, when q_2 reaches a certain level it is no longer a best reply for university 1 to stay on increasing q_1 (probably because the marginal cost of quality is increasing). Its best reply is now situated in another area, i.e. that in which it becomes the lowest quality university. Of course, the same reasoning applies to the reaction function of university 2.

Figure 9 Reaction functions: asymmetric equilibria

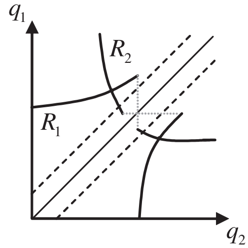
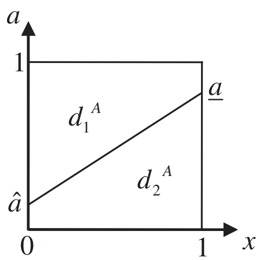


Figure 10 Division of students in an asymmetric equilibrium



for university 1 to invest in teaching compared to university 2, $T_1^A > T_2^A$. Hence, university 1 spends less on research, $R_1^A < R_2^A$. We can show that under conditions (29) and (30), the equilibrium payoff of university 1 always exceeds the equilibrium payoff of university 2: $U_1^A = q_1^A + \gamma R_1^A > U_2^A = q_2^A + \gamma R_2^A$.

Next we derive some comparative statics. In line with previous results, an increase in γ decreases the quality levels, while an increase in η increases the quality levels. Remark that when we neglect the peer group effect ($\eta = 0$), there does not exist an asymmetric equilibrium.

The role of the mobility cost parameter at the asymmetric equilibrium

Consider the following two interesting notes on the role of the mobility cost c in the asymmetric equilibrium. First, as opposed to (26), an increase in the mobility cost c now raises the equilibrium quality levels,

$$\frac{\partial q_1^A}{\partial c} = \frac{c\gamma(-4+\eta)^2(4-3\eta)}{2\sqrt{6}\sqrt{\eta^2(24\eta^2 + c^2\gamma^2(16-16\eta+3\eta^2)^2)}} > 0 \text{ and}$$

$$\frac{\partial q_2^A}{\partial c} = \frac{c\gamma(16-16\eta+3\eta^2)^2}{2\sqrt{6}(4-\eta)\sqrt{\eta^2(24\eta^2 + c^2\gamma^2(16-16\eta+3\eta^2)^2)}} > 0. \quad (33)$$

Again, a change in the mobility cost c affects the average ability of the student body attracted to each university. As opposed to (27), we now find that

$$\frac{\partial^2 \overline{a}_i}{\partial q_i \partial c} = \frac{c}{3(q_1 - q_2)^3} > 0 \text{ for } i = 1, 2. \tag{34}$$

This means that *as the mobility cost increases, the positive effect of an increase in quality on the average ability of a university's student body* ($\frac{\partial \overline{a}_i}{\partial q_i} > 0$) *becomes larger and larger*. It follows that a university will increase the quality provided as the mobility cost increases. Second, we find that the degree of quality differentiation in the asymmetric equilibrium increases with the mobility cost

$$\frac{\partial (q_1^A - q_2^A)}{\partial c} = \frac{c\gamma\eta(16 - 16\eta + 3\eta^2)}{\sqrt{6}\sqrt{\eta^2(24\eta^2 + c^2\gamma^2(16 - 16\eta + 3\eta^2)^2)}} > 0. \tag{35}$$

In fact, this states that as the horizontal differentiation, measured by the size of c, between the universities increases, the vertical differentiation, measured by $q_1^A - q_2^A$, increases as well. This results from (33) and

$$\frac{\partial^2 \overline{a}_1}{\partial q_1 \partial q_2} = \frac{c^2}{2(q_1 - q_2)^4} > 0 \quad \text{and} \quad \frac{\partial^2 \overline{a}_2}{\partial q_2 \partial q_1} = \frac{-c^2}{2(q_1 - q_2)^4} < 0. \tag{36}$$

We know that as c increases both universities increase their quality choice. The increase in q_2 reinforces the gains of an increase in q_1 for university 1, while an increase in q_1 reduces the gains of an increase in q_2 for university 2.

Finally, under conditions (29) and (30), the quality provided by university 1 (2) is higher (lower) than the quality choice of a monopolistic university, $q_2^A < q_m^* < q_1^A$. Moreover, the average quality in this duopoly case exceeds the quality produced by a monopolistic university, $\frac{q_1^A + q_2^A}{2} > q_m^*$.

C. Symmetric or asymmetric equilibrium?

In the previous two subsections we derived sufficient conditions for local symmetric and asymmetric equilibria in quality. See Theorem 2 and 3. In this subsection we want to gain more insight into these equilibria by investigating some numerical examples.

The insights derived from the analysis above and the numerical examples below are somehow comparable to the conclusion of De Fraja and Iossa (2002): the equilibrium configuration depends on the size of the mobility costs. A high mobility cost leads to a symmetric equilibrium, while moderate mobility costs lead to an asymmetric equilibrium. The specific results of our analysis, however, can be summarized as follows. First, we find parameter values (indicated in bold in (37) and (38)) for which the symmetric and the two asymmetric equilibria coexist. Second, at the symmetric equilibrium an increase in c leads to a decrease in teaching quality, and an increase in research levels. At the asymmetric equilibrium, however, the same change would lead to an increase in average teaching quality, an increase in the quality difference, and a decrease in research levels. See Tables (37) and (38) and Figure 11. The reasoning behind this different effect of c was given in the previous two subsections. Remark that if we assume the parameter c to be a policy instrument [17], it is important for the regulator to know whether the universities are at the symmetric or at an asymmetric equilibrium, since the same policy change has different effects on the different equilibria. Third, without mobility costs, both universities reach a corner solution: maximal teaching quality and no research activities. Fourth, in absence of the peer group effect the equilibrium is always symmetric, because it no longer pays for a university to fight for the highest ability students. Moreover, Figure 12 illustrates that this argument holds for low values of the peer group effect as well.

Numerical examples: Table (37) gives the effect of changes in the parameter c on the *symmetric* equilibrium when $\eta = 0.9$, $\gamma = 2$ and $F = 1$:

c	q_1	q_2	$R_1 + R_2$	*stab*	*global*
0.4	0.562	0.562	1.826	**not sat**	**not sat**
0.44	0.547	0.547	1.835	**not sat**	sat
0.45	0.544	0.544	1.837	sat	sat
0.5	**0.531**	**0.531**	**1.845**	**sat**	**sat**
0.6	0.515	0.515	1.854	sat	sat

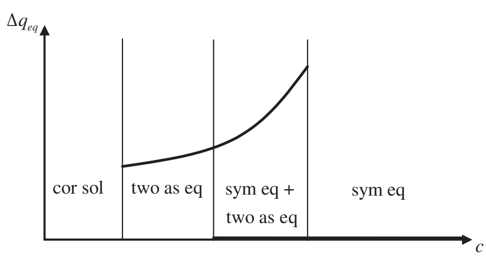
(37)

Table (38) gives the effect of changes in the parameter c on the *asymmetric* equilibrium when $\eta = 0.9$, $\gamma = 2$ and $F = 1$:

c	q_1	q_2	$q_1 - q_2$	$\overline{q}$	$R_1 + R_2$	$q_1 - q_2 \geq c$	*soc*	*stab*	*global*
0.2	0.794	0.333	0.461	0.564	1.851	sat	sat	sat	**not sat**
0.25	0.807	0.339	0.469	0.573	1.844	sat	sat	sat	**not sat**
0.28	0.817	0.342	0.474	0.580	1.839	sat	sat	sat	sat
0.3	0.823	0.345	0.478	0.584	1.835	sat	sat	sat	sat
0.4	0.861	0.361	0.5	0.611	1.814	sat	sat	sat	sat
0.5	**0.906**	**0.380**	**0.526**	**0.642**	**1.788**	**sat**	**sat**	**sat**	**sat**
0.6	0.955	0.401	0.555	0.678	1.756	**not sat**	sat	sat	sat

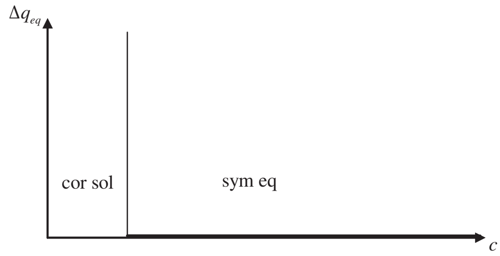
(38)

Figure 11 The relation between the equilibrium quality difference and c when η is high



[17] The regulator could lower c, for instance, by providing free public transport for students.

Figure 12 The relation between the equilibrium quality difference and c when η is low



5. Conclusion

We developed a duopoly model in which publicly funded universities compete in the quality of their teaching. A university's teaching cost is decreasing in the average ability of its student body, and strictly convex in its quality choice. Universities care for research funds as well as teaching quality. Students are characterized by an ability level and a geographical location. The model captures two dimensions of product differentiation. First, the mobility costs students incur when travelling to a university differentiates the universities horizontally. Second, the quality difference between the universities differentiates them vertically. The construction of the students' utility functions in this model implies that, in absence of mobility costs, one half of the student population prefers to enrol in the high quality university, while the other half prefers to enrol in the low quality university. By changing the quality of their teaching universities do not affect their student numbers, but they do affect the average ability levels of their student body. A higher quality university attracts abler students. This allows us to focus on quality competition between universities, and eliminates size effects.

The results of this paper can be summarized as follows. First, we found that both universities will provide the same quality to their students when the horizontal differentiation between the two universities dominates the vertical differentiation between them. This requires a mobility cost which is sufficiently high. Second, if vertical differentiation dominates horizontal differentiation, the universities offer different quality levels. This requires a moderate level of mobility costs. The two results imply that as the mobility cost increases the universities move from the asymmetric to the symmetric equilibrium in quality. Remark, however, that at the symmetric equilibrium an increase in the mobility cost of students leads to a decrease in teaching quality, while at the asymmetric equilibrium the same change causes an increase in teaching quality. Third, if students do not face mobility costs, university competition results into maximal (but symmetric) teaching quality and minimal research activities. Fourth, from our model it also follows that the average teaching quality produced in a duopoly exceeds the quality produced by a monopolist. Finally, we find that if we would drop the assumption that having more talented students allows a university to save on teaching costs, i.e. the peer group effect, the resulting equilibrium would always be symmetric. Moreover, for the asymmetric equilibrium the peer group effect has to be sufficiently high. Otherwise, it does not pay for the universities to fight for the highest ability students.

Within the context of our model it might be interesting to look at the following two extensions. First, we can ask ourselves which quality levels maximize social welfare. Social welfare could e.g. be defined as the sum of the students' utilities minus the costs of education (see, e.g., Del Rey and Romero, 2004). Second, we could include a participation constraint which could be binding for some types of students. Depending on their characteristics (x,a) some students may not find it worthwhile to participate in university education. In this case, the demand for a university will depend on the quality offered and the mobility cost. This will surely influence the competition between universities.

Appendix: No mobility costs ($c = 0$)

In this appendix we show that, assuming that mobility costs are nonexistent, the two universities engage in a kind of Bertrand competition in which both universities always surpass their rival's quality level. This process ends when total funds are devoted to teaching. We think that the same arguments hold for very small levels of the mobility cost.

Given that $c = 0$, a student with ability a enjoys the following utility levels from attending university 1 and 2, respectively,

$$u_1 = \xi + (2a - 1)q_1,$$
$$u_2 = \xi + (2a - 1)q_2. \tag{a1}$$

It follows that students with $a \geq \frac{1}{2}$ prefer the high quality university, while students with $a < \frac{1}{2}$ prefer the low quality university. If $q_1 = q_2$, however, students are indifferent between both universities and enrol randomly. The average abilities of the students enrolling in the two universities become

$$\begin{aligned} \bar{a}_1 &= \tfrac{3}{4}, \quad \bar{a}_2 = \tfrac{1}{4} \quad \Leftrightarrow q_1 > q_2 \\ \bar{a}_1 &= \tfrac{1}{2}, \quad \bar{a}_2 = \tfrac{1}{2} \quad \Leftrightarrow q_1 = q_2 \\ \bar{a}_1 &= \tfrac{1}{4}, \quad \bar{a}_2 = \tfrac{3}{4} \quad \Leftrightarrow q_1 < q_2. \end{aligned} \tag{a2}$$

Both universities maximize their payoff (see (16)) with respect to their quality level q_i, with $\bar{a}_i$ given by (40). It is straightforward, however, that each university wants to attract the highest ability students by just leapfrogging its rival's quality level. In other words, they engage in a kind of Bertrand competition. This results into

$$q_1 = q_2 = q^{\max} = \frac{\sqrt{F}}{\sqrt{1 - \frac{\eta}{2}}}. \tag{a3}$$

In this equilibrium all funds are devoted to teaching, so that no research takes place. Figure (13) illustrates the best reply for university 2 when $c = 0$. Figure (14) illustrates the same process of Bertrand competition for very small values of c. Notice that on both figures there is another *local* best reply. As c increases this best reply becomes global and we reach the asymmetric equilibrium as given in (28).

Figure 13 University 2's best reply when $c = 0$

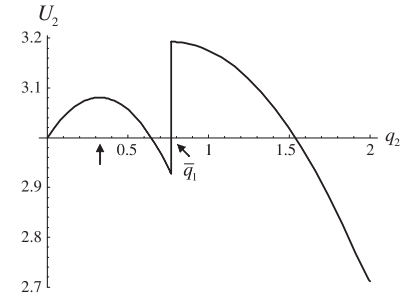
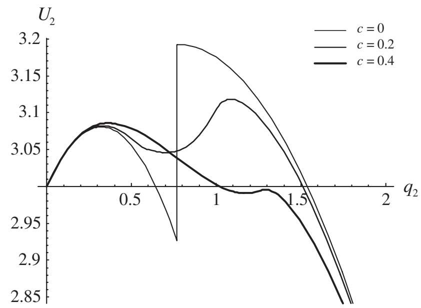


Figure 14 University 2's best reply as c increases



References

Anderson S. P., A. De Palma, and J.-F. Thisse (1992), *Discrete Choice Theory of Product Differentiation*, The MIT Press, London.

Betts J. R. and D. Morell (1999), "The Determinants of Undergraduate Grade Point Average: The Relative Importance of Family Background, High School Resources and Peer Group Effects", *Journal of Human Resources*, 34, pp. 268-293.

De Fraja G. and E. Iossa (2002), "Competition among Universities and the Emergence of the Elite University", *Bulletin of Economic Research*, 54, pp. 275-293.

Degryse H. (1996), "On the Interaction between Vertical and Horizontal Product Differentiation: an Application to Banking", *The Journal of Industrial Economics*, 64(2), pp. 169-181.

Del Rey E. (2001), "Teaching versus Research: A Model of State University Competition", *Journal of Urban Economics*, 49, pp. 356-373.

Del Rey E. and L. Romero (2004), "Competition between Public and Private Universities: Exams versus Prices", Economics Working Papers from Universidad Carlos III.

Del Rey E. and X. Wauthy (2006), "Mención de Calidad: Reducing Inefficiencies in Higher Education Markets when there are Network Externalities", *Investigaciones Económicas*, 30(1), pp. 89-115.

Epple D. and R. Romano (1998), "Competition between Private and Public Schools, Vouchers and Peer Group Effects", *American Economic Review*, 88, pp. 33-63.

HASHIMOTO K. and E. COHN (1997), "Economies of Scale and Scope in Japanese Universities", *Education Economics*, 5(2), pp. 107-115.

JOHNES G. (1997), "Costs and Industrial Structure in Contemporary British Higher Education", *The Economic Journal*, 107, pp. 727-737.

IRMEN A. and J.-F. THISSE (1996), "Competition in Multi-characteristics Spaces: Hotelling was Almost Right", CEPR Discussion Papers nr. 1446.

KEMNITZ A. (2005), "Funding, Competition and Quality in Higher Education", University of Mannheim, http://www.vwl.uni-mannheim.de/.wi/verweise/kemnitz.htm.

KOSHAL R. K. and M. KOSHAL (1999), "Economies of Scale and Scope in Higher Education: a Case of Comprehensive Universities", *Economics of Education Review*, 18, pp. 269-277.

MIRRLEES J.A. (1971), "An Exploration in the Theory of Optimal Income Taxation", *Review of Economic Studies*, 38(114), pp. 175-208.

ROTHSHILD M. and L.J. WHITE (1995), "The Analytics of Pricing in Higher Education and Other Services in Which Customers are Inputs", *Journal of Political Economy*, 103, pp. 573-586.

SÁ C., R. FLORAX and P. RIETVELD (2004), "Determinants of the Regional Demand for Higher Education in the Netherlands: A Gravity Model Approach", *Regional Studies*, 38(4), pp. 375-392.

SPENCE M. (1973), "Job Market Signalling", *Quarterly Journal of Economics*, 87, pp. 355-374.

VANHAECHT E. (2005), "The strategic Importance of Bridging Programs in Higher Education", working paper, Depatment of Economics, University of Antwerp.

WINSTON G.C. (1999), "Subsidies, Hierarchies and Peers: The Awkward Economics of Higher Education", *Journal of Economic Perspectives*, 13, pp. 13-36.

ZIMMERMAN D.J. (2003), "Peer Effects in Academic Outcomes: Evidence from a Natural Experiment", *Review of Economics and Statistics*, 85, pp. 9-23.

Part III

Researcher behavior

Money, fame and the allocation of talent: Brain drain and the institution of science

Doh-Shin JEON and Domenico MENICUCCI[1]

Summary

The earning structure in science is flatter than in the private sector, which could cause a brain drain toward the latter. This paper studies the allocation of talent between both sectors when agents value money and fame. Assuming that the intrinsic performance is a less noisy signal of talent in science than in the private sector, we show that a good institution of science mitigates the brain drain and that introducing extra monetary incentives through the market might induce excessive diversion from pure to applied research. We finally show the optimality of a relatively flat earning structure in science.

"The purest treasure mortal times afford is spotless reputation; that away, men are but gilded loam or painted clay".
William SHAKESPEARE in *Richard II*

1. Introduction

Inducing talented people to become scientists is a national priority for all countries since a nation's economic future is closely linked to its scientific capacity in today's knowledge-based economy. However, the private incentive for a talented agent to choose a scientific career may not be well aligned with the social incentive because she has many other attractive alternatives. For instance, in the U.S., bright

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young people with college degrees can pursue graduate studies in one of the major professional fields such as medicine, law and business. Compared to advanced study in science, these fields promise a much shorter period in school and substantially more lucrative job prospects[2]. This might generate a brain drain from the science sector to the private sector. Currently, both in the U.S. and in Europe, there are concerns about a shortage of scientists and engineers[3].

This paper studies the allocation of talent between the science sector and the private sector in an economy in which each agent makes an occupational choice between becoming a scientist and becoming a professional. We make a departure from the conventional assumption that only monetary payoffs matter and assume that each agent values fame as well. We use a rather narrow definition of fame as the amount of peer recognition that an agent receives as a function of her performance and study the allocation of talent by focusing on the difference between the two sectors in terms of the mapping from talent to performance.

A fundamental difference between the two sectors is that agents in the private sector can more or less appropriate their contribution to the society through profits while scientists (in pure science) cannot because of the public good nature of science. This difference in turn generates another important difference in terms of allocation of fame; the market provides an objective measure of each agent's performance (i.e. her profit) and accordingly distributes fame while the science sector, in order to have an objective measure of each scientist's performance, needs an institution that certifies the scientific contribution of each work. According to the sociologists of science such as Merton (1957, 1973), science is a social institution that defines originality as a supreme value and allocates fame and recognition according to priority so that the augmenting of knowledge and the augmenting of personal fame go hand in hand[4]. This incentive role of peer recognition for scientists is also recognized by Paul Samuelson who said "In the long run, the economic scholar works for the only coin worth having – our own applause" (Merton, 1968, p. 341).

We build a simple model in which each agent has private information about her level of talent and her intrinsic preference between the two occupations (professional and scientist) and the government builds a public science sector. An agent can be either talented or not while her occupational preference has support wide enough that there is a positive fraction of both talented and not-talented agents in each sector. We focus on the refereeing and publication process of the institution of

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[2] Butz *et al*. (2003) compare an estimate of annualized earnings for Ph.D.s with earnings of professional degree holders in U.S. such as MDs, DDSs, DVMs, JDs, and MBAs and find that professional degree holders earn more at nearly every age and considerably more over an entire life career.

[3] For instance, the *New York Times* (May 5, 2004) reports that "The United States faces a major shortage of scientists because too few Americans are entering technical fields and because international competition is heating up for bright foreigners who once filled the gap", referring to the report of National Science Board (2004). Concerning Europe, see the recent report of the European Commission (2003).

[4] According to Merton (1957), the institution of science has developed a priority-based system for allocating (honorific) rewards. Heading the list of recognition is eponymy, the practice of affixing the name of the scientist to all or part of what she has found, as with the Copernican system, Hooke's law and so on. Other rewards include prizes, medals, and memberships in honorary academies. Last, publication and citation constitute rewards available to most scientists.

science and define the quality of the institution as the quality of the mapping from intrinsic outcomes of scientific work to perceived outcomes. The perceived outcome of each scientist is observed by the government and her peers: the former provides monetary rewards and the latter provide non-monetary rewards (i.e. peer recognition) depending on the perceived outcome. In contrast, in the case of professionals, we do not make any distinction between intrinsic and perceived outcomes since we assume that each professional's profit is observable.

We investigate three related issues in this setting. First, we study the brain drain generated by lower monetary returns to talent in science and how it is affected by peer recognition and the quality of the institution of science. Second, we study how the availability of additional monetary incentives through the market (for instance, from licensing patents) affects the brain drain and social welfare. Last, we consider a more general framework in which the government uses two instruments (wages and research grants) in order to investigate whether a relatively flat earning structure in science can arise as an optimal feature.

In the absence of fame, a brain drain toward the private sector arises in our basic model because we assume that the monetary reward to talent is higher in the private sector than in the science sector. This assumption is true in (Continental) Europe in which most institutions of higher education follow a system based on seniority where performance has virtually no impact on salary[5]. It also holds in the US since the profile of earnings in science is known to be rather flat[6] while the returns to talent in the private sector are large[7]. We could find only weak evidence of the brain drain in the US: the number of US citizens with very high GRE-score (> 750) headed for science and engineering graduate studies declined by more than 8 % between 1992 and 2000 (Zumeta and Raveling, 2002)[8]. However, predictions of a shortage of scientists both in Europe and the US on the one hand and increasing rewards to talent in the private sector[9] on the other hand well justify our concerns about the brain drain.

Central in our model is the assumption that the intrinsic outcome of a scientist is a less noisy signal of talent than that of a professional in the private sector. This gives

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[5] See Aghion and Cohen (2004), Perotti (2002) and the *Wall Street Journal Europe* (September 3, 2004). For instance, according to Perotti's study of the promotion to full professorship in economics in Italy, (i) an outsider needs 13 more refereed publications than an insider in order to compensate for the latter's advantage, and (ii) even in the competition among outsiders, the effect of a publication in a high-quality journal is not statistically different from the effect of a publication in a low-quality journal.

[6] The average full professor earns only about 38 to 109 percent more than the average new assistant professor depending on the discipline (Ehrenberg, 1991). Even the best-paid professor in the fifty leading universities seldom receives three times as much salary as the worst-paid professor (Stigler, 1988).

[7] Although Butz *et al.* show that professionals make more money than Ph.D.s, there is no empirical work comparing the monetary rewards to talent in both sectors. However, top money managers, for instance, can earn more than $250 million a year (*New York Times*, August 5, 2005) and it is needless to say that no professor's salary can be that high.

[8] They also find that among US citizens and long-term residents, the share of the science and engineering majors from leading colleges or universities planning immediate advanced study in a science or engineering discipline fell from 17 % in 1984 to 12 % in 1998.

[9] See the literature on superstars (Rosen, 1981), complementarity and positive sorting (Kremer, 1993), skill-biased technological changes (Caselli, 1999) and the finance literature on CEO compensation (Murphy, 1999).

peer recognition a potential role in attracting talent to science. We have three justifications for this assumption. First, research is traditionally individual work while business is team work: the average number of authors per research paper is four (Adams *et al.* 2005) while production and marketing processes of a firm involve a much larger number of people. Second, originality has a supreme value in science while in other professions without much team work such as lawyers and medical doctors, tasks are relatively routine and repetitive: a path-breaking discovery is a clear sign of genius while one does not need to be a genius in order to perform routine tasks well. Last, openness (i.e. making one's discovery public) is the norm in science because of priority recognition while secrecy is the norm in the private sector because of profit seeking, which makes the filtering out of noise in performance more difficult in the private sector. As a consequence of these assumptions, the expected non-pecuniary reward to talent in terms of peer recognition is higher in science than in the private sector when the institution of science is perfect.

As a benchmark, we study the first-best allocation of talent when the government can observe each agent's level of talent and occupational preference and dictate her occupational choice. It is widely believed that real innovation in science depends less on the many "worker bees" than on the presence of a small number of great minds. This, together with the huge positive externality of a great scientific discovery on society, would make talent more productive in science than in the private sector. Then, in the first-best outcome, the fraction of scientists is higher among talented agents than among not-talented agents.

Under incomplete information about talent, the government can make the wage of a scientist depend only on her perceived outcome. We assume an upper bound on the wage differential within the science sector that makes the monetary reward to talent lower in science than in the private sector. In the absence of utility from fame, this leads to a brain drain toward the private sector. However, when agents derive utility from fame, a good institution of science can mitigate the brain drain (and may even achieve the first-best allocation) by providing a non-monetary reward to talent higher than the one in the private sector while a bad institution of science exacerbates it.

In Section 4, we introduce extra monetary incentives through the market into our model. For instance, the Bayh-Dole Act (1980) was introduced in the U.S. to foster interactions between academia and the business community. The Act enables universities to claim ownership of the intellectual property rights generated from federally funded research and provides scientists with opportunities to earn money, and most OECD countries emulated the American experience. We study how the availability of extra monetary rewards from licensing patents affects scientists' research pattern and what its consequence is on brain drain and on social welfare. However, we depart from a simple linear relationship between basic and applied science and introduce what we call the Pasteur's Quadrant (PQ)[10] coefficient to capture the degree to which

[10] *Pasteur*'s *Quadran*t is the title of the book written by Stokes (1997) who mainly argues against the standard distinction between basic and applied science as two distinct categories by pointing out that Pasteur made pioneering discovery although he was motivated to find solutions to practical problems. Rosenberg (2004) also argues in a similar spirit that causation between science and technology runs both ways.

basic research can generate patentable scientific knowledge. We find that when the PQ coefficient is high, introducing the licensing opportunity does not affect research patterns, reduces the brain drain and increases social welfare. In contrast, when the coefficient is low, introducing the licensing opportunity can induce excessive diversion from pure to applied research, which might reduce social welfare even while it reduces the brain drain. We also find that the licensing opportunity is more likely to enhance welfare when the institution of science is good since a good institution of science makes excessive diversion less likely.

In Section 5, we study the optimal balance between monetary and non-monetary incentives in science in a general setting in which the government uses two instruments: wages and research grants. We assume that there are no restrictions on wages (in order to eliminate the issue of brain drain) and that the government observes an individual signal correlated with a scientist's talent and awards research grants as a function of the signals. We characterize the optimal balance between monetary and non-monetary incentives in terms of what we call *the benefit-adjusted social marginal cost of providing grants*, which decreases with the quality of the institution of science. This implies that as the quality of the institution increases, one should increase the relative weight of the non-monetary incentive over the monetary one and, in particular, we show that a relatively flat earning structure in science is optimal when the institution of science is good and scientists highly value priority recognition.

Although there are papers on the economics of science that refer to the sociology of science (Dasgupta and Paul, 1987 and 1994; Stephan, 1996), they have not built any formal model to study the allocation of talent between the private sector and the science sector. Furthermore, the existing literature on the brain drain under asymmetric information initiated by Kwok and Leland (1982) studies only the migration from one country to another but does not study the brain drain from the science sector to the private one in a closed economy.

In terms of modeling incentives from non-monetary rewards, our paper is related to Benabou and Tirole (2006) and Besley and Ghatak (2005). The former builds a signaling model in which reputation from social groups provides incentives to engage in pro-social behavior such as blood donation. The latter studies the incentive issues in mission-oriented organizations such as schools and find a potential benefit of the market in inducing a good match among the principals and the agents with different mission preferences. Both papers focus on how non-monetary rewards can help to solve moral hazard while we focus on how non-monetary rewards can help to screen agents with different levels of talent.

With respect to the principal-agent theory, our paper is related to the literature on non-responsiveness (Guesnerie and Laffont, 1984), which focuses on a strong conflict between the allocation preferred by the principal and the allocations implementable under incentive constraints. In our paper, the conflict arises since the principal (the government) wants the fraction of scientists among talented agents to be larger than the fraction among not-talented agents while the incentive constraints may force the principal to implement only those allocations in which the latter is larger than the former. Our problem is symmetric to the one analyzed by Jeon and

Laffont (1999, 2006) who study the optimal mechanism for downsizing the public sector when workers have private information on their productivity although they consider neither science nor fame.

Regarding the papers on the allocation of talent (Acemoglu and Verdier, 1998 and 2000; Murphy *et al.*, 1991; Grossman and Maggi, 2000, and Grossman, 2004), none of them models fame or studies the allocation of talent between the science sector and the private sector.

The paper is organized as follows. Section 2 describes the basic model. Section 3 analyzes the model and focuses on the brain drain. Section 4 analyzes how the availability of extra monetary incentives through the market affects the research pattern, the brain drain and social welfare. Section 5 analyzes the optimal balance between monetary and non-monetary incentives in science. Concluding remarks are gathered in Section 6. All the proofs are in Appendix.

2. The basic model

In this section, we describe the basic model that is used in Section 3. In Section 4 and Section 5, we extend the basic model in different directions.

A. *Occupations, adverse selection and outcomes*

There is a mass one of risk-neutral agents in the economy. Let I be the set of all the agents. Each agent should make an occupational choice between becoming a professional in the private sector and becoming a scientist. Although in reality a lot of scientific research is carried out by the private sector, in our model "becoming a professional" is equivalent to "going to the private sector". Agent i has private information about her level of talent (or intelligence), denoted by θ_i, and her intrinsic preference between the two professions, denoted by γ_i. For simplicity, θ_i can take on two values: $\theta_i \in \Theta \equiv \{T,N\}$; $\theta_i = T$ is called a talented type and $\theta_i = N$ is called a not-talented type. Since we focus on the choice between professional and scientist, we do not lose much generality by considering a one-dimensional talent space[11]. θ_i is identically and independently distributed. Let $v \in (0,1)$ denote the probability that $\theta_i = T$; hence $1 - v = \Pr\{\theta_i = N\}$. When we do not refer to a specific agent, we drop the subscript i; for instance, we use θ instead of θ_i.

γ_i represents *the difference* between the intrinsic (non-monetary) pleasure that agent i derives from being professional and the intrinsic pleasure from being scientist such that $\gamma_i < 0$ means that agent i has a relative preference for scientist over professional. For instance, the intrinsic pleasure from becoming scientist can include love of science or satisfaction from solving puzzles (Levin and Stephan, 1991). Since what matters for social welfare is each agent's choice between the two professions and intrinsic pleasure affects agent i's choice only through the relative pleasure γ_i, we normalize, without loss of generality, each agent's absolute pleasure from becoming scientist at zero. For simplicity, we assume that γ_i is identically and independently distributed over i according to a uniform distribution with support

[11] By contrast, if we study a choice between entrepreneur and researcher, we need to consider a multi-dimensional type space since to be a good entrepreneur, one needs multiple skills (Lazear, 2005).

$[-\gamma, \gamma]$ and that there is no correlation between θ_i and γ_i. We discuss a case of correlation in Section 6.

Let $O_i \in \{R,S\}$ represent agent i's occupational choice: $O_i = R$ ($O_i = S$) when she becomes professional (scientist). We assume for simplicity that the outcome that an agent realizes after choosing an occupation has a binary support: it can be high or low. More precisely, a type θ scientist realizes a high outcome (i.e. a path-breaking discovery) with probability p_θ^S and a low outcome (i.e. an ordinary discovery) with probability $1 - p_\theta^S$. We focus on pure scientific research that does not produce any direct monetary gain to the scientist but increases the productive potential of the future economy. We assume that the social monetary value of a path-breaking discovery is $s^H > 0$ and that of an ordinary discovery is $s^L \in (0,s^H)$. A type θ professional produces a high profit $\pi^H > 0$ with probability p_θ^R and a low profit $\pi^L \in (0,\pi^H)$ with probability $1 - p_\theta^R$. Obviously, $\Delta p^O \equiv p_T^O - p_N^O > 0$ for $O \in \{R, S\}$. Let $S_\theta \equiv p_\theta^S s^H + (1 - p_\theta^S) s^L$ and $\Pi_\theta \equiv p_\theta^R \pi^H + (1 - p_\theta^R)\pi^L$.

B. Institution of science and fame

There are many factors affecting the quality of the institution of science. In this paper, we take a narrow angle and focus on the refereeing and publication process. We define the quality of the institution of science as the quality of the mapping from the intrinsic outcomes of scientists to the perceived outcomes. The intrinsic outcome refers to the original value of a scientific work, and the perceived outcome refers to the certification label that the work receives through the refereeing and publication process. The intrinsic outcome is either high or low as described in Section 2, A. We assume that the perceived outcome is either high or low as well. Let $q_r \in \left[\frac{1}{2}, 1\right]$ denote the probability that a high intrinsic outcome is perceived as high, which is assumed for simplicity to be equal to the probability that a low intrinsic outcome is perceived as low. Therefore, q_r is a measure of the quality of the institution of science[12].

Regarding the definition of fame, we consider an individual's fame as the recognition she gets from her peers. The amount of recognition that agent i receives is assumed to increase with the level of her outcome perceived by the peers. For simplicity, we assume that if agent i's perceived outcome is low, she gets zero recognition while if it is high, she gets a unit amount of recognition[13]. Therefore, the expected fame of a type θ scientist is $\beta_\theta \equiv p_\theta^S q_r + (1 - p_\theta^S)(1 - q_r)$, the probability that she will have a high perceived outcome. For a professional we suppose that her outcome is publicly observable; thus the expected fame for a type θ professional is p_θ^R.

We make the following assumption:

Assumption 1: *The intrinsic outcome is a less noisy signal of talent in science than in the private sector* (*i.e.* $\Delta p^S > \Delta p^R$).

12 q_r means quality of refereeing.

13 The quality of the institution of science can affect the amount of recognition that one obtains from a high perceived outcome. Including this aspect into our model does not affect our results qualitatively.

We gave in the introduction three reasons for why assumption 1 is likely to hold. This assumption implies that when the quality of the institution of science is perfect (i.e. $q_r = 1$), the difference between a talented agent's expected fame and that of a not-talented agent is larger in the science sector than in the private sector; in other words, the non-pecuniary reward to talent in terms of fame is higher in the former than in the latter.

Agent i's payoff U_i is given as follows:

$$U_i = m_i + af_i + \gamma_i \mathbf{1}_{[O_i = R]}$$

where m_i is her monetary income, a (≥ 0) is the weight parameter for fame, and f_i is her fame.

C. Government

The government pays wages to induce agents to become scientists and can make a scientist's wage contingent on her perceived outcome. Let w be the basic salary that every scientist earns and $b \geq 0$ the bonus that a scientist receives if her perceived outcome is high; the bonus can be interpreted as the increase in salary following a promotion resulting from good publications.

We assume that there is an upper bound on b, denoted by $\overline{b} > 0$, that satisfies the following assumption.

Assumption 2: The monetary reward to talent is higher in the private sector than in science: $\Delta p^R (\pi^H - \pi^L) > \Delta p^S \overline{b}$.

The inequality says that the difference between a talented professional's expected profit and that of a not-talented one is higher than the difference between a talented scientist's expected monetary income and that of a not-talented one, even when $q_r = 1$. This implies that the monetary reward to talent is larger in the private sector than in the science sector for any value of $q_r \in \left[\frac{1}{2}, 1\right]$. Assumption 2 captures the stylized fact that monetary incentives are lower-powered in academia than in the private sector. We provided detailed justifications of the assumption in the introduction.

In order to describe how an agent chooses her occupation, we notice that the payoff that a type θ agent with γ_i expects to have after becoming a professional is given by $\Pi_\theta + \gamma_i + ap_\theta^R$ [14], while her payoff if she becomes a scientist is $w + \beta_\theta (b + \alpha)$. Thus, the agent chooses to become a scientist if the following inequality holds:

$$w + \beta_\theta(b + a) \geq \Pi_\theta + \gamma_i + ap_\theta^R.$$

Let φ_T (φ_N) denote the fraction of the talented (not-talented) agents becoming scientists. Social welfare, denoted by SW, is given as follows:

$$SW \equiv v(1 - \varphi_T)\Pi_T + (1 - v)(1 - \varphi_N)\Pi_N + v\varphi_T S_T + (1 - v)\varphi_N S_N + \int_{I_R} \gamma_i di.$$

[14] If we consider agent i's utility from entering the private sector as her reservation utility, it is type-dependent through θ_i and has a random component γ_i as in Rochet and Stole (2002).

where I_R is the set of agents who choose a professional career. We assume that the government maximizes the above objective regardless of whether $\alpha > 0$ or $\alpha = 0$. In other words, we suppose that the government does not care about recognition per se but cares about it only because it affects the individual professional choices, and thus φ_T and φ_N. In reality, it is hard to measure the aggregate level of fame or recognition in an economy and to make the government accountable for it[15].

D. *Timing*

We consider a game with the following timing:

1. For each $i \in I$, nature draws θ_i and γ_i and they become agent i's private information.
2. The government announces $\{w,b\}$.
3. Each agent makes her occupational choice.
4. Each agent's outcome is realized.
5. Each scientist receives the basic wage w and, in case of a high perceived outcome, also the bonus b.

3. Allocation of talent and brain drain

A. *First best benchmark: complete information outcome*

In this subsection we derive as a benchmark the first best allocation of talent, the allocation that maximizes social welfare when the government has complete information about each agent i's talent θ_i and occupational preference γ_i and can dictate each agent's occupational choice. In the next subsection we examine a more realistic setting in which each agent i has private information about (θ_i, γ_i) and makes her occupational choice.

It is straightforward to see that to realize a given $\varphi_\theta \in (0,1)$ for $\theta \in \{T,N\}$, it is socially optimal that there exists a cut-off type $\gamma_\theta = \gamma\,(2\varphi_\theta - 1) \in (-\gamma,\gamma)$ such that all type θ agents with $\gamma_i \geq \gamma_\theta$ ($\gamma_i < \gamma_\theta$) become professional (scientist). Therefore, $(\varphi_T, \varphi_N) \in [0,1]^2$ represents an allocation of talent between the two occupations and the sum of the agents' intrinsic pleasure from their occupations given (φ_T, φ_N) is

$$\int_{I_R} \gamma_i di = v \int_{\gamma(2\varphi_T - 1)}^{\gamma} \frac{z}{2\gamma} dz + (1-v) \int_{\gamma(2\varphi_N - 1)}^{\gamma} \frac{z}{2\gamma} dz$$
$$= \gamma\,[v\varphi_T\,(1 - \varphi_T) + (1 - v)\varphi_N\,(1 - \varphi_N)].$$

Hence, social welfare is given as follows[16]:

$$SW(\varphi_T, \varphi_N) \equiv v(1 - \varphi_T)\Pi_T + (1 - v)(1 - \varphi_N)\Pi_N + v\varphi_T S_T + (1 - v)\varphi_N S_N$$
$$+ \gamma\,[v\varphi_T\,(1 - \varphi_T) + (1 - v)\varphi_N\,(1 - \varphi_N)].$$

[15] Furthermore, what people care about is often relative recognition rather than absolute recognition and when we aggregate relative recognition, its sum is zero by definition.

[16] Recall that social welfare does not depend on fame, as we explained in Section 2, C.

The government maximizes SW with respect to (φ_T, φ_N) in $[0,1]^2$. The first order conditions (for an interior allocation) are given as follows[17]:

$$\Pi_T + \gamma(2\varphi_T - 1) = S_T, \tag{1}$$

$$\Pi_N + \gamma(2\varphi_N - 1) = S_N. \tag{2}$$

These conditions show that, for each $\theta \in \{T,N\}$, the social marginal value that the cut-off type produces as a professional is equal to the one she produces as a scientist, where social marginal values take into account the intrinsic preferences for occupations. The next proposition characterizes the first-best allocation of talent, denoted by $(\varphi_T^{FB}, \varphi_N^{FB})$ [18].

Proposition 1. *(The first-best) The first-best allocation of talent is given by*

$$\varphi_T^{FB} = \frac{\gamma - \Pi_T + S_T}{2\gamma}, \qquad \varphi_N^{FB} = \frac{\gamma - \Pi_N + S_N}{2\gamma}. \tag{3}$$

In $(\varphi_T^{FB}, \varphi_N^{FB})$, the fraction of scientists is larger among talented agents than among not-talented agents if and only if talent is more productive in the science sector than in the private sector: $\varphi_T^{FB} > \varphi_N^{FB}$ if and only if $S_T - S_N > \Pi_T - \Pi_N$.

We note that the first best allocation does not depend on α since the objective of the government is independent of α and there is no constraint on the allocation of talent that it can choose. In the rest of the paper we make the following assumption, which implies $\varphi_T^{FB} > \varphi_N^{FB}$:

Assumption 3: *Talent is more productive in the science sector than in the private sector:* $S_T - S_N > \Pi_T - \Pi_N$.

Note that $S_T - S_N = \Delta p^S (s^H - s^L)$. It is widely believed that real innovation in science depends less on the many "worker bees" than on the presence of a small number of great minds (i.e. Δp^S is high). This fact, together with the huge positive externality of a great scientific discovery on society (i.e. $s^H - s^L$ is high), makes assumption 3 quite plausible.

B. *Incomplete information outcome: with and without fame*

In this subsection we assume that each agent i privately observes (θ_i, γ_i) and chooses her occupation. We study the government's optimal choice of (w,b), and in particular, we focus on how the incomplete information, together with assumption 2 and the condition $0 \leq b \leq \bar{b}$, restricts the set of implementable allocations of talent.

We start by noticing that in order to achieve an interior allocation of talent $(\varphi_T, \varphi_N) \in (0,1)^2$, it is necessary that (w,b) satisfy the following incentive constraints:

$$(IC_T) \quad \Pi_T + ap_T^R + 2\gamma\varphi_T - \gamma = w + \beta_T(b + a); \tag{4}$$

[17] Throughout the paper we assume that the optimal allocations are interior; in the proofs in the appendix we describe the conditions under which this is the case. Allowing for corner allocations is straightforward but complicates the exposition without yielding any additional insight.

[18] We remark that it is possible to implement the first best allocation by using a market mechanism under weaker assumptions on the government's information and power. More precisely, it suffices that the government observes the talent of each agent and makes an agent's wage depend on her talent.

$$(IC_N) \quad \Pi_N + \alpha p_N^R + 2\gamma\varphi_N - \gamma = w + \beta_N(b + \alpha). \tag{5}$$

If (IC_θ) holds, all type-θ agents with intrinsic occupational preference higher (lower) than $2\gamma\varphi_\theta - \gamma$ become professionals (scientists) since the type with preference $2\gamma\varphi_\theta - \gamma$ is indifferent between the two occupations. Then, the fraction of type-θ agents becoming scientists is just φ_θ.

In order to solve (4)-(5) with respect to (w,b), we notice that $\beta_T - \beta_N = \Delta p^S(2q_r - 1)$, and thus $q_r > \frac{1}{2}$ implies $\beta_T > \beta_N$. Therefore it is possible to solve (4)-(5) with respect to (w,b) as long as $q_r \in (\frac{1}{2}, 1]$, and the solution is given by

$$w = \frac{\beta_T A_N - \beta_N A_T}{\beta_T - \beta_N}, \qquad b = \frac{A_T - A_N}{\beta_T - \beta_N}, \tag{6}$$

where A_θ is the left hand side in (IC_θ) minus $\beta_\theta \alpha$. Hence, for any given allocation (φ_T, φ_N) including the first best $(\varphi_T^{FB}, \varphi_N^{FB})$, if $q_r > \frac{1}{2}$, we can find a pair (w,b) that implements (φ_T, φ_N) if we neglect the constraint that b must belong to $[0, \bar{b}]$.

Simple manipulations show that b in (6) satisfies $b \leq \bar{b}$ if and only if

$$\varphi_N - \varphi_T \geq \frac{\Pi_T - \Pi_N - \Delta p^S(2q_r - 1)\bar{b} + \alpha[\Delta p^R - \Delta p^S(2q_r - 1)]}{2\gamma}. \tag{7}$$

In order to interpret this condition, consider first the case without fame (i.e. $\alpha = 0$). Then, under assumption 2, the first best $(\varphi_T^{FB}, \varphi_N^{FB})$ can never be implemented for any given $q_r \in \left[\frac{1}{2}, 1\right]$. In other words, for any $q_r \in \left[\frac{1}{2}, 1\right]$, (7) is violated at $(\varphi_T, \varphi_N) = (\varphi_T^{FB}, \varphi_N^{FB})$ since the monetary reward to talent in the private sector $(\Pi_T - \Pi_N)$ is larger than the maximal monetary reward to talent in science $(\Delta p^S(2q_r - 1)\bar{b})$ on the one hand, and $\varphi_T^{FB} > \varphi_N^{FB}$ holds on the other hand. Furthermore, this argument also shows that no allocation satisfying $\varphi_T \geq \varphi_N$ is feasible when $\alpha = 0$. Intuitively, given a cut-off type γ_N for not-talented agents, it is impossible to induce a talented agent i with $\gamma_i \geq \gamma_N$ to become a scientist because the monetary reward to talent in the private sector is larger than the one in science.

In the case of $\alpha > 0$, instead, the non-pecuniary reward to talent in the private sector is equal to $\alpha\Delta p^R$, while the one in science is $\alpha(\beta_T - \beta_N) = \alpha\Delta p^S(2q_r - 1)$. From assumption 1, when $q_r = 1$, the latter is larger than the former. In contrast, when $q_r = \frac{1}{2}$, the latter is zero and thus smaller than the former. Therefore, there exists a threshold $\hat{q}_r \in (\frac{1}{2}, 1)$ such that the non-pecuniary reward to talent is larger in science than in the private sector if and only if the quality of the institution of science is higher than $\hat{q}_r$. Formally, $[\Delta p^R - \Delta p^S(2q_r - 1)]$ in (7) is negative if and only if $q_r > \hat{q}_r$. Then it is clear that, when $q_r > \hat{q}_r$, the first best can be achieved if α is sufficiently large because then the right hand side of (7) is negative enough and this makes (7) satisfied at $(\varphi_T, \varphi_N) = (\varphi_T^{FB}, \varphi_N^{FB})$. In other words, if $q_r > \hat{q}_r$ and α is large, the first-best is implementable because the non-pecuniary reward to talent in science is much larger than the one in the private sector and outweighs the difference in the monetary rewards.

When the first-best allocation cannot be achieved, we find the second-best allocation of talent by solving the following program[19]:

$$\max_{(\varphi_T, \varphi_N) \in [0,1]^2} SW \text{ subject to } (7). \tag{8}$$

We denote the solution to (8) by $(\varphi_T^*, \varphi_N^*)$. The next proposition summarizes our results about the implementation of the first best and characterizes $(\varphi_T^*, \varphi_N^*)$.

Proposition 2. *(incomplete information) Suppose that (θ_i, γ_i) is agent i's private information and that assumptions 1 to 3 are satisfied. Then*

(i) The first best allocation $(\varphi_T^{FB}, \varphi_N^{FB})$ is achievable if and only if satisfies (7), which occurs if and only if the institution of science is good enough $(q_r > \hat{q}_r)$ and the weight on fame α is sufficiently large. In particular, $(\varphi_T^{FB}, \varphi_N^{FB})$ can never be implemented if α = 0.

(ii) If the first best allocation cannot be achieved, then the second best allocation of talent $(\varphi_T^*, \varphi_N^*)$ is characterized by

$$\begin{aligned} \varphi_T^* &= \varphi_T^{FB} - \frac{\mu^*}{2\nu\gamma} = \nu\varphi_T^{FB} + (1-\nu)\varphi_N^{FB} - (1-\nu)B, \\ \varphi_N^* &= \varphi_N^{FB} + \frac{\mu^*}{2(1-\nu)\gamma} = \nu\varphi_T^{FB} + (1-\nu)\varphi_N^{FB} + \nu B, \end{aligned} \tag{9}$$

where $\mu^* = 2\nu(1-\nu)\gamma(B + \varphi_T^{FB} - \varphi_N^{FB}) > 0$ is the multiplier associated with the constraint (7) and B is the right hand side in (7). The second-best is such that

a. There is a brain drain from the science sector to the private sector: $\varphi_T^{FB} > \varphi_T^*$;

b. If B > 0, which occurs if α is zero or small enough, then the fraction of not-talented agents becoming scientists is larger than that of talented agents: $\varphi_N^* > \varphi_T^*$

c. (comparative statics on the brain drain)

— As the quality of the institution of science increases, the brain drain decreases: $\frac{\partial(\varphi_T^{FB} - \varphi_T^*)}{\partial q_r} < 0$;

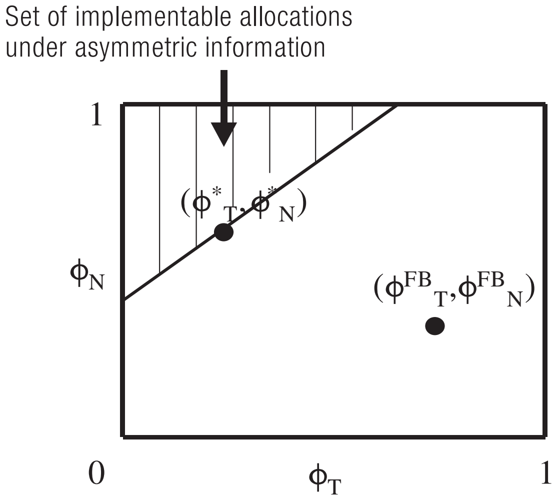
— As the weight on fame α increases, there is less (more) brain drain if the quality of the institution of science is higher (lower) than $\hat{q}_r$: $\frac{\partial(\varphi_T^{FB} - \varphi_T^*)}{\partial \alpha} \gtreqless 0$ if $q_r \lesseqgtr \hat{q}_r$.

Proposition 2 establishes that if α is small enough, the first best is not achievable, and then there is a brain drain from the science sector to the private sector in that the number of talented scientists is smaller in the second best than in the first-best outcome: $\varphi_T^* < \varphi_T^{FB}$. Figure 1 describes the first-best and the second-best allocations of talent in this case. As we have mentioned above, the brain drain is generated by assumption 2, according to which the cap on the bonus in the science sector $\bar{b}$ makes the monetary reward to talent in the science sector smaller than the one in the private sector for any q_r. In addition, this gives talented agents larger incentives to become professionals than not-talented agents, which makes the fraction of scientists larger among not-talented agents than among talented agents: $\varphi_N^* > \varphi_T^*$.

The institution of science has an important effect on the allocation of talent. A good institution of science improves the allocation and mitigates the brain drain

[19] Since in the first best the inequality $b \leq \bar{b}$ is violated, we will find $b = \bar{b}$ in the second best; hence $b \geq 0$ is satisfied.

Figure 1 The first-best and the second-best allocations of talent in the absence of fame



by increasing both the monetary and non-monetary reward to talent in science. In particular, if the agents put sufficient weight a on fame, a good institution of science allows the government to achieve the first-best allocation. If the first-best cannot be attained, how $a > 0$ affects the brain drain depends on the quality of the institution of science. Specifically, if the quality of the institution of science is bad such that the non-pecuniary reward to talent in terms of fame is larger in the private sector than in the science sector, an increase in a makes choosing a professional career even more attractive to talented agents and therefore aggravates the brain drain. Thus, the existence of fame reduces the brain drain only if the quality of the institution is above a certain level. It is important to notice, however, that the results related to the effect of fame crucially depend on assumption 1. If that assumption is violated, then the non-pecuniary reward to talent is larger in the private sector than in science. As a result, the set of implementable allocations is reduced by the presence of fame (for any q_r) and, in particular, the first best is never achievable.

Our results suggest a possible explanation for the fact that, in the past, the western countries succeeded in inducing talented people to become scientists without giving large monetary returns to talent: building a good institution of science generated large non-pecuniary returns to talent in science that compensated for the lower monetary rewards to talent.

4. Extra monetary rewards through the market and the allocation of talent

Salary and bonus are not the only sources of income for scientists since they can generate revenue from consulting fees, patents, prizes and so on. In particular, in U.S., the Bayh-Dole Act (1980) was introduced to foster interactions between academia and the business community: by enabling universities to claim ownership of the intellectual property rights generated from federally funded research, the Act provides scientists in academia with incentives to commercialize their inventions. Emulating the American experience, several member countries of OECD sought, beginning in the mid-1990s, to encourage commercialization of technology developed at universities.

In this section, we extend our model to study how the availability of extra monetary rewards through the market (in particular from licensing patents) affects scientists' research pattern and what its consequence is on brain drain (i.e. on the set of implementable allocations of talent) and on social welfare. One of the main concerns regarding the Bayh-Dole Act is that it can divert scientists' research from basic science to applied one (Cohen *et al*., 1998; Florida 1999; National Science Board, 2004; Thursby and Thursby, 2003)[20]. We focus on this aspect and consider a simple moral hazard problem; each scientist decides whether to divert some effort from basic to applied research. However, we depart from a simple linear relationship between basic and applied science and introduce what we call the Pasteur's Quadrant (PQ) coefficient, denoted by y_b (> 0)[21], to capture the fact that basic research can to some extent generate patentable scientific knowledge. Therefore, even though a scientist does not divert her effort, she can make extra money from the licensing opportunity. More precisely, if a type-θ scientist does not divert her effort, with probability p_θ^S she makes a path-breaking discovery, which generates an expected social benefit of y_b from licensing in addition to s^H[22]. If there is diversion, her probability to make a path-breaking discovery decreases by Δ_θ (with $p_\theta^S > \Delta_\theta > 0$ and $p_T^S - \Delta_T > p_N^S - \Delta_N$) and the (expected) social benefit from licensing is equal to $(p_\theta^S - \Delta_\theta)y_b + \Delta_\theta y_a$ with $y_a > 0$ (the subscript *a* means applied science). We assume that a scientist captures a share $\delta \in (0,1]$ of the social value generated from licensing and that the government cannot make a scientist's salary depend on whether or not she diverts effort, as it is the case in reality.

We start by making the following assumption on $s^H - s^L$:

Assumption 4: $\delta(s^H - s^L) > \bar{b} + a$.

To explain assumption 4, suppose for the moment that $q_r = 1$. In this case, if a scientist makes a path-breaking discovery instead of an ordinary one, social welfare increases by $s^H - s^L$ while her monetary payoff increases by $b \leq \bar{b}$ and her payoff from fame by a. In general, the private return $(b + a)$ from a great discovery induces a scientist to internalize only partially the social return $(s^H - s^L)$, which means that $s^H - s^L > b + a$. Assumption 4 is stronger than this inequality and says that the private return is lower than the share δ of the social return.

[20] However, the empirical evidence is mixed. For instances, Cohen *et al*. (1998) provide evidence of countervailing effects of industry collaboration on faculty productivity in terms of publications while Thursby and Thursby (2003) find that licensing did not affect the portion of faculty's research that is published in basic journals.

[21] The subscript *b* means basic science.

[22] Note that we assume that the market is efficient in that even when a path-breaking discovery is recognized as a low outcome, it generates y_b. This makes sense since although an important discovery is not published in a top journal, it can obtain a patent.

We first analyze the private and social incentives to divert research and compare the two. Given (w,b), the payoff of a type-θ scientist is $w + \delta p_\theta^S y_b + \beta_\theta(b+\alpha)$ if she does not divert her research and $w + \delta[(p_\theta^S - \Delta_\theta)y_b + \Delta_\theta y_a] + (\beta_\theta - (2q_r - 1)\Delta_\theta)(b+\alpha)$ otherwise. Therefore, regardless of her type, she diverts her research if and only if the PQ coefficient is lower than the threshold y_b^P given by

$$y_b^P \equiv \frac{\delta y_a - (2q_r - 1)(b + \alpha)}{\delta}.$$

In what follows, for expositional simplicity, we assume $y_b^P > 0$, which holds if δy_a is large relative to $b + \alpha$, or if q_r is close to $\frac{1}{2}$ [23].

The social benefit generated by a type θ scientist is $p_\theta^S(s^H + y_b) + (1 - p_\theta^S)s^L = S_\theta + p_\theta^S y_b$ if she fully dedicates herself to basic research and $(p_\theta^S - \Delta_\theta)(s^H + y_b) + (1 - p_\theta^S + \Delta_\theta)s^L + \Delta_\theta y_a = S_\theta + p_\theta^S y_b + \Delta_\theta(y_a - s^H + s^L - y_b)$ otherwise. Therefore, it is socially desirable that a scientist diverts her research if and only if the PQ coefficient is lower than the threshold $y_b^S \equiv y_a - (s^H - s^L)$, regardless of her type[24]; notice that assumption 4 implies $y_b^S < y_b^P$. The first part of next proposition describes when the private and the social incentives of diverting research are aligned, and when they are not, given that the licensing opportunity exists. The second part considers a fixed allocation of talent and analyzes the social desirability of introducing the opportunity.

Proposition 3. *Suppose that the government provides scientists with the opportunity to patent and license their findings. Suppose assumption 4 and $y_b^P > 0$.*

(i) (research pattern) We have two cases:
Case 1: when $y_b \geq y_b^P$. Providing the licensing opportunity does not affect scientists' research pattern and no change in research pattern is socially desirable.
Case 2: when $y_b \in (0, y_b^P)$. Providing the licensing opportunity induces scientists to divert part of their attention from basic to applied science. If $y_b^S > 0$ and $y_b \in (0, y_b^S)$, this change is socially beneficial; otherwise (i.e. if $y_b \in (y_b^S, y_b^P)$), the change is socially detrimental.

(ii) (desirability of Bayh-Dole Act for a given allocation of talent)
a. Providing the licensing opportunity always increases social welfare in case 1. In contrast, in case 2, it increases social welfare when

$$y_b^S \geq 0, \quad or \quad y_b^S < 0 \quad and \quad y_b > \frac{\Delta_\theta}{p_\theta^S - \Delta_\theta}|y_b^S| \quad for \quad \theta = T,N; \tag{10}$$

it decreases social welfare when

$$y_b^S < 0 \quad and \quad y_b < \frac{\Delta_\theta}{p_\theta^S - \Delta_\theta}|y_b^S| \quad for \quad \theta = T,N. \tag{11}$$

[23] The restriction to $y_b^P > 0$ allows us to reduce the number of cases and actually leaves us with the most interesting cases. Indeed, if $y_b^P \leq 0$ then $y_b \geq y_b^P$ is satisfied and we are always in case 1 (in the terminology of Propositions 3 and 4 below).

[24] In particular, diverting research is never socially optimal if $s^H > s^L + y_a$ since this implies $y_b^S < 0$.

b. As the institution of science improves, y_b^P decreases, and therefore it is more likely that providing the licensing opportunity increases social welfare.

Proposition 3(i) reveals the importance of the PQ coefficient y_b in determining the impact of the licensing opportunity on the research pattern. In particular, it shows that if the coefficient is smaller than y_b^P, then the licensing opportunity can create a conflict since it leads scientists to divert research from basic to applied science even though this may be socially undesirable. As a consequence of the conflict, for a fixed allocation of talent, proposition 3(ii)a states that providing the opportunity decreases social welfare (with respect to not introducing the opportunity) for low values of y_b, if $s^H - s^L > y_a$. Even though we do not model different research fields, in reality the value of y_b should depend on the field: for instance, it should be high for life science and engineering and low for physics and astronomy. Finally, an increase in the quality of the institution decreases y_b^P, which in turn enlarges the zone of case 1 in which there is no conflict between private and social incentives. Therefore, the licensing opportunity is more likely to increase social welfare the better the institution of science is because it makes it less likely that scientists will divert their research.

Proposition 3(ii) about the social desirability of the Bayh-Dole Act applies for a given allocation of talent, but it is clear that the licensing opportunity also affects the allocation of talent through the monetary and non-monetary reward to talent. In order to examine this effect of the Act, we suppose from now on that before the licensing opportunity is available, the constraint $b \leq \bar{b}$ binds and generates a brain drain as described in Section 3, B. We say that the licensing opportunity reduces (worsens) the brain drain if it enlarges (reduces) the set of implementable allocations of talent. Let $\bar{y}_b^P \equiv y_a - \frac{1}{\delta}(2q_r - 1)(\bar{b} + a)$ be the value of y_b^P when $b = \bar{b}$. We have

Proposition 4. *(brain drain) Suppose that the government provides scientists with the opportunity to patent and license their research in a setting characterized by brain drain.*

(i) We have two cases:

Case 1: when $y_b \geq \bar{y}_b^P$. Providing the opportunity reduces the brain drain.

Case 2: when $y_b \in (0, \bar{y}_b^P)$.

a. When talented scientists divert research more than not-talented scientists do ($\Delta_T \geq \Delta_N$); providing the licensing opportunity reduces the brain drain.

b. When talented scientists divert research less than not-talented scientists do ($\Delta_T < \Delta_N$); there is a threshold $\hat{y}_b (< \bar{y}_b^P)$ such that providing the opportunity reduces (worsens) the brain drain if $y_b > \hat{y}_b$ (if $y_b < \hat{y}_b$), where

$$\hat{y}_b \equiv \bar{y}_b^P \frac{\Delta_N - \Delta_T}{\Delta p^S + \Delta_N - \Delta_T}.$$

(ii) As the institution of science improves, both $\hat{y}_b$ and $\bar{y}_b^P$ decrease; thus providing the licensing opportunity is more likely to reduce the brain drain.

Providing the licensing opportunity reduces (worsens) the brain drain if it increases (decreases) the reward to talent in science. When the PQ coefficient is high (i.e. case 1), providing the opportunity reduces the brain drain since there is no change in research pattern and a talented scientist's expected income from licensing is higher than that of a not-talented one by $\delta\Delta p^S y_b > 0$.

When the PQ coefficient is low (i.e. case 2), there is a change in the research pattern that affects the reward to talent in science through two channels. First, there is a direct effect from licensing income. Type θ earns a licensing income equal to $\delta[(p_\theta^S - \Delta_\theta)y_b + \Delta_\theta y_a]$, originated from basic and applied research. Thus, the monetary reward to talent varies by $\delta[\Delta p^S y_b + (\Delta_T - \Delta_N)(y_a - y_b)]$; in particular, since $y_a > y_b$ holds in case 2, the monetary reward to talent increases if $\Delta_T \geq \Delta_N$. Second, there is an indirect effect since the change in research pattern affects the information structure in science. For instance, if $\Delta_T > \Delta_N$ holds, this makes the intrinsic outcome of science a noisier signal of talent and thereby reduces the reward to talent provided by the institution of science by $(2q_r - 1)(\Delta_T - \Delta_N)(\bar{b} + \alpha)$. Therefore, the total effect on the reward to talent in science is given by

$$\begin{aligned} & \delta\Delta p^S y_b + (\Delta_T - \Delta_N)[\delta(y_a - y_b) - (2q_r - 1)(\bar{b} + \alpha)] \\ = \; & \delta[\Delta p^S y_b + (\Delta_T - \Delta_N)(\bar{y}_b^P - y_b)]. \end{aligned}$$

Since $\bar{y}_b^P > y_b$ in case 2 and $\Delta p^S y_b > 0$, we see that providing the licensing opportunity always reduces the brain drain when $\Delta_T \geq \Delta_N$. In contrast, if $\Delta_T < \Delta_N$ holds, then the change in the reward to talent is $(\Delta_T - \Delta_N)\,\bar{y}_b^P < 0$ if $y_b = 0$ but is increasing with y_b since $\Delta p^S > \Delta_T - \Delta_N$. Thus, there is a threshold $\hat{y}_b$ such that the availability of licensing opportunity worsens the brain drain if and only if $y_b < \hat{y}_b$.

We think that the availability of licensing opportunity is likely to reduce the brain drain since $\Delta_T \geq \Delta_N$ seems to be more probable than $\Delta_T < \Delta_N$. For instance, if both types divert the same amount of time to applied research and this reduces their probabilities of success by the same fraction, then $\Delta_T > \Delta_N$ follows from $p_T^S > p_N^S$. Alternatively, it is reasonable to think that p_N^S is quite small and close to zero while p_T^S is substantially larger; thus it is plausible that Δ_T is larger than $p_N^S\ (\geq \Delta_N) \simeq 0$. However, we stress that even though the brain drain decreases, a large reduction of talented agents' productivity in pure research can be socially harmful, especially if s^H is much larger than s^L; see Proposition 3(ii)a and its proof.

Finally, since an increase in the quality of the institution of science decreases both $\bar{y}_b^P$ and $\hat{y}_b$, we conclude that providing the licensing opportunity is more likely to reduce the brain drain when the institution of science is good.

In order to evaluate the global effect of the licensing opportunity on social welfare, we observe that social welfare definitely increases (decreases) if social welfare increases (decreases) for any given allocation and the availability of the licensing opportunity enlarges (reduces) the set of implementable allocations. Therefore, the following corollary results from Propositions 3 and 4.

Corollary 1. *Suppose that the licensing opportunity is introduced in a setting with a brain drain. Then*

(i) it increases social welfare when $y_b \geq \bar{y}_b^P$ or when $\hat{y}_b < y_b < \bar{y}_b^P$ and (10) is satisfied. It decreases social welfare when $y_b < \hat{y}_b$ and (11) is satisfied;

(ii) it is more likely to increase social welfare when the institution of science is good.

Although this corollary does not cover all the parameter values, the main insight is clear. First, introducing the licensing opportunity improves social welfare if the PQ coefficient is sufficiently large, while it may decrease social welfare if the coefficient is small enough. Second, a good institution of science makes introducing the licensing opportunity more likely to be welfare-enhancing.

5. Optimal balance between monetary and non-monetary rewards in science

In this section we consider a general setting in which the government, in addition to paying wages to scientists, distributes research grants. The grants affect a scientist's non-monetary reward by affecting her probability to make a path-breaking discovery. Furthermore, we drop assumptions 1-3 and assume away any constraint on wages such as the cap on bonus $\bar{b}$ we considered in the previous sections. As we explain later in the section, this implies that any given allocation can be implemented by the government with a suitable wage structure, and therefore there is no issue of brain drain in this section. In this general setting, we study two following problems: we first investigate the optimal balance between the monetary and non-monetary rewards in science and how the balance should vary depending on parameters such as the quality of the institution of science; second, we compare the monetary reward to talent in science with the one in the private sector. In particular, we show the optimality of relatively flat wages in science. For this purpose, we enrich the basic model in three respects.

First, after each agent makes her occupational choice, for each scientist i, the government observes a signal σ_i which is positively correlated with θ_i but is not correlated with θ_j for any $j \neq i$. The signal can be either good or bad: $\sigma_i \in \{G,B\}$. For instance, σ_i represents scientist i's performance in the early stages of her career. Let $q_s \in (\frac{1}{2}, 1]$ represent the quality, or precision, of the signal in the following sense:

$$q_s \equiv \Pr\{\sigma_i = G \,|\theta_i = T\} = \Pr\{\sigma_i = B|\, \theta_i = N\}.$$

For simplicity, however, we assume that recognition depends only on the (final) perceived outcome and not on the early signal.

Second, the government allocates research grants to scientist i on the basis of σ_i; let g_G (g_B) represent the research grant given to scientist i when $\sigma_i = G$ (when $\sigma_i = B$). A scientist's probability of making a path-breaking discovery depends both on her talent and on her research grant. More precisely, let $p^S_\theta(g)$ represent the probability for a type-θ scientist to make a path-breaking discovery when she receives grant g. Assumption 5 below specifies the properties of the functions $p^S_T(g)$ and $p^S_N(g)$.

Last, we introduce a positive shadow cost of public funds $\lambda > 0$, meaning that each dollar spent by the government is raised through distortionary taxes (labor, capital and commodity taxes) and costs society $1 + \lambda$ dollars (Laffont and Tirole, 1993). In the case of $\lambda = 0$, neither α nor q_r has any impact on the optimal balance between the monetary and non-monetary rewards since the government can costlessly replicate any non-monetary reward in science through wages, which are pure transfers. When $\lambda > 0$, instead, a trade-off exists between monetary and non-monetary rewards.

We suppose that $s^H - s^L > \alpha$[25], and make the following assumption regarding $p_T^S(g)$ and $p_N^S(g)$:

Assumption 5:

(i) $p_T^S(0) \geq p_N^S(0)$ *and* $\frac{dp_T^S}{dg} \geq \frac{dp_N^S}{dg} \geq 0$ *for any* $g > 0$; $\frac{dp_N^S(0)}{dg} > \frac{1+\lambda}{s^H - s^L}$;

(ii) $0 > \frac{d^2 p_T^S}{dg^2} > \frac{d^2 p_N^S}{dg^2}$ *whenever* $\frac{dp_N^S}{dg} > 0$.

The first part of the assumption says that the marginal productivity of grants is positive and is larger for a talented scientist than for a not-talented scientist; the assumption on $\frac{dp_N^S(0)}{dg}$ implies that the optimal g is strictly positive for both signals. The second part says that the marginal productivity decreases and it does so faster for a not-talented scientist than for a talented scientist.

In what follows, we proceed in two steps. First, we fix an allocation of talent (φ_T, φ_N) that the government wants to achieve and study the optimal balance between monetary and non-monetary rewards and how this balance is affected by a change in parameters α, q_r, λ. Second, we characterize the optimal allocation of talent.

Let m_θ^e represent the expected monetary payoff for a type θ scientist. Since $q_s > \frac{1}{2}$ and there is no constraint on the wage schedule, the arguments given at the beginning of Section 3, C show that any pair (m_T^e, m_N^e) is attainable by the government. Specifically, the government may choose (for instance) a wage schedule with a fixed term plus a bonus linked to the signal σ_i[26].

As in the previous sections, β_θ is the probability for a type θ scientist to get a high perceived outcome. It is now given by

$$\beta_T \equiv \left[q_s p_T^S(g_G) + (1 - q_s) p_T^S(g_B)\right] q_r + \left[1 - (q_s p_T^S(g_G) + (1 - q_s) p_T^S(g_B))\right](1 - q_r); \quad (12)$$

$$\beta_N \equiv \left[q_s p_N^S(g_B) + (1 - q_s) p_N^S(g_G)\right] q_r + \left[1 - (q_s p_N^S(g_B) + (1 - q_s) p_N^S(g_G))\right](1 - q_r). \quad (13)$$

Arguing as in Section 3, B, we find that in order to implement a given (interior) allocation (φ_T, φ_N), it is necessary and sufficient that (m_T^e, m_N^e, g_G, g_B) satisfy the following incentive constraints:

$$(IC_T) \quad \Pi_T + 2\gamma\varphi_T - \gamma + \alpha p_T^R = m_T^e + \alpha\beta_T; \quad (14)$$

$$(IC_N) \quad \Pi_N + 2\gamma\varphi_N - \gamma + \alpha p_N^R = m_N^e + \alpha\beta_N. \quad (15)$$

Note first that the left hand side of (IC_θ) represents the reservation utility of a type-θ scientist having $\gamma_i = 2\gamma\varphi_\theta - \gamma$. Given an allocation of talent, this reservation utility is fixed. Therefore, an increase in g_G or g_B increases the non-pecuniary rewards to both types of scientist through an increase in the probability to make a path-breaking discovery, and this in turn decreases the monetary rewards m_T^e and m_N^e by (14)-(15).

Since (φ_T, φ_N) is given, the contribution to social welfare generated by the private sector is constant and the objective of the government is the social welfare generated

[25] This condition is weaker than assumption 4 and was explained when assumption 4 was introduced.

[26] This schedule is similar to the one of Section 3, C, but the bonus is obtained when $\sigma_i = G$.

by science minus the social cost of salaries and grants. We denote this objective by SW^S and let $S_\theta(g) \equiv p^S_\theta(g)s^H + (1 - p^S_\theta(g))s^L$ for $\theta \in \{N,T\}$ represent the expected social surplus generated by a type θ scientist who receives grant g. Then, we have

$$\begin{aligned} SW^S \quad = \quad & q_s \{v\varphi_T [S_T(g_G) - (1+\lambda)g_G] + (1-v)\varphi_N [S_N(g_B) - (1+\lambda)g_B]\} \\ & +(1-q_s)\{v\varphi_T [S_T(g_B) - (1+\lambda)g_B] + (1-v)\varphi_N [S_N(g_G) - (1+\lambda)g_G]\} \\ & -\lambda [v\varphi_T m^e_T + (1-v)\varphi_N m^e_N]. \end{aligned}$$

We can express m^e_T and m^e_N as functions of (g_G, g_B) from (14) and (15) and insert them into SW^S. We obtain a (concave) function of (g_G, g_B), and therefore the following first-order conditions are necessary and sufficient for maximization[27]:

$$v\varphi_T q_s \left(\frac{dp^S_T(g_G)}{dg_G} - k\right) + (1-v)\varphi_N(1-q_s)\left(\frac{dp^S_N(g_G)}{dg_G} - k\right) = 0; \qquad (16)$$

$$v\varphi_T(1-q_s)\left(\frac{dp^S_T(g_B)}{dg_B} - k\right) + (1-v)\varphi_N q_s\left(\frac{dp^S_N(g_B)}{dg_B} - k\right) = 0; \qquad (17)$$

where

$$k \equiv \frac{1+\lambda}{s^H - s^L + \alpha\lambda(2q_r - 1)}.$$

We below give an economic interpretation of k through the special case of perfect correlation between σ_i and θ_i (i.e. $q_s = 1$). Then, we find

$$\frac{dp^S_T(g_G)}{dg_G} = k = \frac{dp^S_N(g_B)}{dg_B}.$$

Consider a unitary increase in g_G, for instance. On the one hand, the social marginal cost of providing a unit of grant is $1 + \lambda$. On the other hand, there are two social marginal benefits. One is the *direct social benefit* from an increased probability of having the path-breaking discovery, which is equal to $\frac{dp^S_T(g_G)}{dg_G}(s^H - s^L)$. The other is the *indirect social benefit* related to the fact that the increase in the non-monetary reward in terms of fame allows the government to reduce the monetary reward necessary to achieve the given allocation of talent, which is equal to $\frac{dp^S_T(g_G)}{dg_G}\alpha\lambda(2q_r - 1)$. Therefore, the total social marginal benefit is $\frac{dp^S_T(g_G)}{dg_G}[s^H - s^L + \alpha\lambda(2q_r - 1)]$. Observe that the numerator of k is the social marginal cost of grants while the denominator represents the social marginal benefit from an increase in p^S_T. Therefore, we call k the *benefit-adjusted social marginal cost of providing grants*. In the extreme case of $\lambda = 0$, k is independent from α and q_r. In this case, non-monetary rewards in science have no role since the government can use costless monetary transfers (salaries and bonuses) to replicate any non-monetary reward; therefore, the optimal research grants are determined by simply equalizing the direct social benefit from grants and the social cost of grants. Let $(g^*_G(\alpha, q_r, \lambda), g^*_B(\alpha, q_r, \lambda))$ denote the optimal grants and $(m^{e*}_T(\alpha, q_r, \lambda), m^{e*}_N(\alpha, q_r, \lambda))$ the optimal expected salaries. We have the following proposition:

[27] We have $g_G > 0$ and $g_B > 0$ in the optimum because of assumption 5(i). Furthermore, a unique solution to (16)-(17) exists because $\frac{dp^S_T}{dg}$ and $\frac{dp^S_N}{dg}$ are strictly decreasing and $\frac{dp^S_\theta(g)}{dg} \to 0$ as $g \to +\infty$ (by assumption 5(ii)).

Proposition 5. *(optimal monetary and non-monetary rewards) Suppose that (θ_i, γ_i) is agent i's private information and that $s^H - s^L > \alpha$. Under assumption 5 and given an allocation of talent $(\varphi_T, \varphi_N) \in (0,1)^2$ that the government wants to implement,*

(i) The optimal monetary and non-monetary rewards $(g_G^*, g_B^*, m_T^{e*}, m_N^{e*})$ are characterized through k, the benefit-adjusted social marginal cost of providing grants, by (14)-(17).

(ii) (comparative statics)

a. (balance between the two rewards) Both grants g_G^* and g_B^* decrease with k and therefore the monetary rewards to both types m_T^{e*} and m_N^{e*} increase with k;

b. k is decreasing with respect to the weight on fame α and the quality of the institution of science q_r; k is increasing with respect to the shadow cost of public funds λ.

The optimal balance between monetary and non-monetary rewards is characterized through k, the benefit-adjusted social marginal cost. By (16)-(17), an increase in k reduces both grants (hence, the non-monetary rewards for both types), which in turn increases, from (14) and (15), the monetary rewards for both types. Proposition 5 (ii) shows how each parameter affects this balance through k. An increase in the weight on fame α, an increase in the quality of the institution of science q_r, and a decrease in the shadow cost of public funds λ all shift the balance from monetary reward to non-monetary reward by decreasing k. To understand how a change in λ affects the balance, note that as λ increases, both the total social benefits from grants $s^H - s^L + \alpha\lambda\,(2q_r - 1)$ and the social cost of grants $1 + \lambda$ increase. However, since a scientist does not fully internalize the social benefit from a path-breaking research (i.e. $s^H - s^L > \alpha$), we have $s^H - s^L > \alpha\,(2q_r - 1)$. This implies that the increase in the total benefits is relatively smaller than the increase in the cost and therefore k increases with λ. Hence, as λ increases, it is optimal to decrease grants while increasing salaries.

Now we compare the monetary reward to talent in science with the one in the private sector. Since the mapping between the talent and the outcome is endogenous through the choice of grants, we introduce a modified version of assumption 1 as follows. Define $\underline{g}$ by $\frac{dp_N^S(g)}{dg} = \frac{1+\lambda}{s^H - s^L}$. Then, we have $g_G^*(\alpha, q_r, \lambda) > g_B^*(\alpha, q_r, \lambda) \geq \underline{g} > 0$ for all (α, q_r, λ).

Assumption 1': $\Delta \underline{p}^S \equiv p_T^S(\underline{g}) - p_N^S(\underline{g}) > \Delta p^R$.

This assumption is a sufficient condition to make the intrinsic outcome a less noisy signal of talent in science than in the private sector when grants are chosen optimally, for any (α, q_r, λ). From (14)-(15), the difference between the monetary reward to talent in the private sector $(\Pi_T - \Pi_N)$ and the one in science $(m_T^{e*} - m_N^{e*})$ is given by

$$\alpha\,[(\beta_T - \beta_N) - \Delta p^R] - 2\gamma\,(\varphi_T - \varphi_N). \tag{18}$$

We now give sufficient conditions for the optimality of lower monetary rewards to talent in science than in the private sector.

Proposition 6. *(relatively flat monetary rewards in science) Suppose that* (θ_i, γ_i) *is agent i's private information and that assumptions 1' and 5 are satisfied. Given an allocation of talent* $(\varphi_T, \varphi_N) \in (0,1)^2$ *that the government wants to achieve, the monetary reward to talent in science is lower than the one in the private sector if* $\varphi_T \leq \varphi_N + \Phi$*, with* $\Phi \equiv \frac{\alpha}{2\gamma}[(2q_r - 1)\Delta \underline{p}^S - \Delta p^R]$*; thus,* $\Phi > 0$ *if* $q_r > \underline{q}_r \equiv (\Delta \underline{p}^S + \Delta p^R)/2\Delta \underline{p}^S > \frac{1}{2}$.

Proposition 6 says that the optimal incentive structure is such that the monetary reward to talent in the science sector is lower than the one in the private sector for all allocations satisfying $\varphi_T \leq \varphi_N + \Phi$, where $\Phi > 0$ if the quality of the institution of science is good enough (i.e. $q_r > \underline{q}_r$). Moreover, Φ is (linearly) increasing with respect to α if $q_r > \underline{q}_r$. Therefore, the monetary reward to talent should be lower in science than in the private sector *for any* allocation (φ_T, φ_N) if α is large enough and $q_r > \underline{q}_r$. Hence, proposition 6 provides one possible rationale for the commonly observed relatively flat wages in science. The insight here is similar to the one in Section 3, C: the science sector can provide a high non-monetary reward to talent given that the intrinsic outcome is a less noisy signal of talent in science than in the private sector.

We now study the optimal allocation of talent. Given that salaries and grants are chosen optimally, as described above, the social welfare is given by

$$\begin{aligned} SW(\varphi_T, \varphi_N) &= \nu(1-\varphi_T)\Pi_T + (1-\nu)(1-\varphi_N)\Pi_N + \gamma\,[\nu\varphi_T(1-\varphi_T) + (1-\nu)\varphi_N(1-\varphi_N)] \\ &\quad + SW^S(\varphi_T, \varphi_N, g_G^*(\varphi_T, \varphi_N), g_B^*(\varphi_T, \varphi_N)). \end{aligned}$$

Using the envelope theorem, we find the first order conditions for an interior maximum):

$$\begin{aligned} \Pi_T + \gamma(2\varphi_T - 1) &= q_s[S_T(g_G^*) - (1+\lambda)g_G^*] + (1-q_s)[S_T(g_B^*) - (1+\lambda)g_B^*] - \lambda(m_T^{e*} + 2\gamma\varphi_T) \\ \Pi_N + \gamma(2\varphi_N - 1) &= q_s[S_N(g_B^*) - (1+\lambda)g_B^*] + (1-q_s)[S_N(g_G^*) - (1+\lambda)g_G^*] - \lambda(m_N^{e*} + 2\gamma\varphi_N). \end{aligned}$$

The left hand side represents the social gain that the marginal agent who is indifferent between the two professions produces as a professional while the right hand side represents the social gain that she produces as a scientist. The right hand side is composed of the social gain from research minus the social cost of grants and wages: the last term $m_\theta^{e*} + 2\gamma\varphi_\theta$ is equal to $\frac{\partial(\varphi_\theta m_\theta^{e*})}{\partial\varphi_\theta}$, which is the increase in the wage bill $\varphi_\theta m_\theta^{e*}$ induced by a marginal increase in φ_θ.

6. Concluding remarks

The earning structure in science is known to be flat relative to the one in the private sector, and this raises concerns about the brain drain from the science sector to the private sector. This paper points out that since performance is a less noisy signal of talent in the science sector than in the private sector, if agents care about both money and peer recognition, a good institution of science can mitigate the brain drain by providing a high non-pecuniary reward to talent. Furthermore, when the institution of science is good and scientists care a lot about priority recognition, a relatively flat earning structure in science is likely to be optimal. Despite the desirability of providing strong monetary and non-monetary incentives to scientists, one should be cautious with introducing extra monetary incentives through the market by encouraging research for commercialization. For instance, the extra incentives can induce too much shift from basic to applied research and thereby result in a lower social welfare.

Our results suggest that the current increase in team size in science[28] might have a negative consequence in terms of the brain drain. For instance, in an experimental article in physics, the author list can be longer than the article and in such a case the role of the individual scientist is hard to evaluate. In fact, Merton (1968) argues that the growth of team work makes the recognition of individual contributions by others problematic.

It would be interesting to study how recognition from non-peers affects the allocation of talent. In general, outsiders would have difficulty telling whether a professor has a good or bad publication record, but it would be easy for them to know about the institution to which a professor belongs. Since non-peers would give more recognition to professors of prestigious universities than to professors of mediocre universities, and becoming professor of a prestigious university would generally require talent, a hierarchical organization of universities as in the US could increase the reward to talent in terms of non-peer recognition and hence mitigate the brain drain. In contrast, in (Continental) Europe, most universities are local monopolies and therefore there is not much quality differentiation among them.

If all agents highly value autonomy or freedom in academia, this should make wages in academia lower than the one in the private sector as in Aghion *et al*. (2005). Although this can be easily captured in our model with a negative mean value of γ_i for both types of agents, we would like to emphasize that our focus is not about the absolute wage differential between the two sectors but about the relatively flat monetary reward to talent in science.

In reality, the intrinsic pleasure from being a scientist (such as the pleasure from solving puzzles) may be positively correlated with talent, implying that the mean value of γ_i conditional on $\theta_i = T$ is smaller than the one conditional on $\theta_i = N$ in our setting. We find that in this case, compared to the case of no correlation, the set of implementable allocations of talent expands, but the first-best allocation has a higher φ_T^{FB} and a lower φ_N^{FB} such that the first-best cannot be implemented under incomplete information in the absence of fame as long as the earning structure is flatter in science than in the private sector. Furthermore, an explanation entirely based on the positive correlation cannot shed any light on the role of the institution of science as a mechanism distributing priority recognition emphasized by Merton.

In our model, the public sector is active while the private sector is passive in that the government actively induces talented agents to become scientists while taking their outside options in the private sector as given. However, in reality, things can be more complex since the private sector is at least as much interested in attracting talented people as the government is, and therefore the government's attempt to attract talented people might induce the private sector to bid up their wages.

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[28] Adams *et al*. find that team size increased by 50 percent in the U.S. over the period 1981-1999.

Finally, the various benefits from having a good institution of science that this paper identified suggest that the government might intervene to improve the institution. Regarding the intervention of the government, we can distinguish two different dimensions: the intervention in the certification (i.e. referring) process and the intervention to improve dissemination of knowledge. On the one hand, we did not consider the possibility for the government to improve the certification process, which seems to be a delicate issue. Since academia enjoys a substantial degree of autonomy (at least in western countries), it seems difficult for the government to find ways to improve the accuracy of refereeing[29]. Therefore, we restricted the government to perform only its most traditional role of paying wages and allocating research funds. On the other hand, electronic publishing seems to offer new opportunities to improve dissemination of scientific knowledge. For instance, the recent report on the market for academic journals commissioned by European Commission (2006) recommends the creation of an open access repository in Europe and the experimentation of open access journals. However, there exist concerns that private interests of commercial publishers having market power might be in conflict with the realization of the potential gain from the electronic publishing[30].

Appendix

Proof of Proposition 1

The first order conditions (1)-(2) are necessary and sufficient for the optimality of an interior allocation since SW is strictly concave in (φ_T, φ_N). Hence, (3) is optimal if it is interior, which is the case if and only if $\gamma > S_\theta - \Pi_\theta > -\gamma$ for $\theta \in \{N,T\}$.

Proof of Proposition 2

Let $B = \frac{1}{2\gamma}\{\Pi_T - \Pi_N - \Delta p^S(2q_r - 1)\bar{b} + a[\Delta p^R - \Delta p^S(2q_r - 1)]\}$ for the sake of brevity and define the Lagrangian function by $L \equiv SW + \mu(\varphi_N - \varphi_T - B)$, where μ is the multiplier associated with (7). Then, the first-order conditions are given by[31]

$$\frac{\partial L}{\partial \varphi_T} = v(-\Pi_T + S_T + \gamma(1 - 2\varphi_T)) - \mu = 0, \tag{19}$$

$$\frac{\partial L}{\partial \varphi_N} = (1 - v)(-\Pi_N + S_N + \gamma(1 - 2\varphi_N)) + \mu = 0. \tag{20}$$

It is straightforward to find $\varphi_T^* = \frac{v(S_T - \Pi_T + \gamma) - \mu^*}{2v\gamma} = \varphi_T^{FB} - \frac{\mu^*}{2v\gamma}$ and $\varphi_N^* = \frac{(1-v)(\gamma - \Pi_N + S_N) + \mu^*}{2(1-v)\gamma} = \varphi_N^{FB} + \frac{\mu^*}{2(1-v)\gamma}$ from (19)-(20). If $\mu = 0$, then we obtain $(\varphi_T^{FB}, \varphi_N^{FB})$ provided that (7) is satisfied at $(\varphi_T, \varphi_N) = (\varphi_T^{FB}, \varphi_N^{FB})$. When $q_r > \hat{q}_r$ we have that $\Delta p^R - \Delta p^S(2q_r - 1) < 0$, and (7) holds at $(\varphi_T^{FB}, \varphi_N^{FB})$ if

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[29] However, we admit that the design of optimal incentives for refereeing is a very interesting issue for future research.

[30] For instance, big commercial publishers' bundling practices can force the libraries to spend too much money on their journals, which leaves little money for small publishers and builds entry barriers (Edlin and Rubinfeld, 2004; Jeon and Menicucci, 2006).

[31] Since SW is strictly concave and (7) is linear, the first order conditions for the Lagrangian are necessary and sufficient for the optimality of an interior allocation.

α is large enough. If (7) is violated at $(\varphi_T^{FB}, \varphi_N^{FB})$, then $\mu^* > 0$ and (7) binds at $(\varphi_T^*, \varphi_N^*) = (\varphi_T^{FB} - \frac{\mu^*}{2\nu\gamma}, \varphi_N^{FB} + \frac{\mu^*}{2(1-\nu)\gamma})$. Plugging these values into (7) yields $\mu^* = 2\nu(1-\nu)\gamma(B + \varphi_T^{FB} - \varphi_N^{FB}) > 0$ and (9). We find that $(\varphi_T^*, \varphi_N^*)$ is interior if and only if $2\gamma(1 - \nu B) > \nu(\gamma - \Pi_T + S_T) + (1-\nu)(\gamma - \Pi_N + S_N) > 2\gamma(1-\nu)B$, a condition that is satisfied if γ is sufficiently large. Since $\mu^* > 0$, we obtain (iia). Result (iib) holds because $B > 0$ when $\alpha = 0$ or α is close to zero, by assumption 2. About result (iic) we note that as q_r increases or $\bar{b}$ increases, B decreases and therefore φ_T^* increases: see (9). When α increases, B increases or decreases depending on whether $\Delta p^R - \Delta p^S(2q_r - 1) > 0$ or $\Delta p^R - \Delta p^S(2q_r - 1) < 0$, which is equivalent to saying $q_r < \hat{q}_r$ or $q_r > \hat{q}_r$.

Proof of Proposition 3

(i) The proof is done in the main text.

(ii) Without the opportunity, the contribution to social welfare of a type θ scientist is S_θ. After the opportunity is introduced, and given the change in the research pattern, the contribution of the same type θ scientist is $S_\theta + (p_\theta^S - \Delta_\theta)y_b + \Delta_\theta y_b^S$. This is larger than S_θ if $y_b^S \geq 0$, or if $y_b^S < 0$ and $y_b > \frac{\Delta_\theta}{p_\theta^S - \Delta_\theta}|y_b^S|$.

Proof of Proposition 4

(i) We analyze only the non-trivial Case 2 in which $y_b < \bar{y}_b^P$, because the licensing opportunity does not affect the research pattern in Case 1, and then the monetary (non-monetary) reward to talent increases by $\delta\Delta p^S y_b > 0$ (does not change). The inequality $y_b < \bar{y}_b^P$ requires $\bar{y}_b^P > 0$, which is satisfied if and only if $\bar{b} + \alpha \leq \delta y_a$ holds, or $\bar{b} + \alpha > \delta y_a$ and q_r is close enough to 1. Arguing as in Section 3, B, we find the incentive constraints that (w, b) needs to satisfy in order to implement a given interior allocation (φ_T, φ_N):

$$\begin{aligned} \Pi_T + \alpha p_T^R + 2\gamma\varphi_T - \gamma &= w + \delta[(p_T^S - \Delta_T)y_b + \Delta_T y_a] \\ &\quad + (\beta_T - (2q_r - 1)\Delta_T)(b + \alpha), \end{aligned} \tag{21}$$

$$\begin{aligned} \Pi_N + \alpha p_N^R + 2\gamma\varphi_N - \gamma &= w + \delta[(p_N^S - \Delta_N)y_b + \Delta_N y_a] \\ &\quad + (\beta_N - (2q_r - 1)\Delta_N)(b + \alpha). \end{aligned} \tag{22}$$

After solving (21)-(22) with respect to (w,b), we find that $b \leq \bar{b}$ reduces to

$$\begin{aligned} &\Pi_T - \Pi_N + 2\gamma(\varphi_T - \varphi_N) + \alpha\Delta p^R \leq \\ &\delta[(\Delta_T - \Delta_N)(y_a - y_b) + \Delta p^S y_b] + (2q_r - 1)(\Delta p^S - \Delta_T + \Delta_N)(\bar{b} + \alpha). \end{aligned} \tag{23}$$

With respect to (7), the right hand side of (23) includes the additional term $\delta[(\Delta_T - \Delta_N)(y_a - y_b) + \Delta p^S y_b] + (2q_r - 1)(\Delta_N - \Delta_T)(\bar{b} + \alpha)$. Therefore, (23) is less restrictive than (7) if and only if $\delta[(\Delta_T - \Delta_N)y_a + (\Delta p^S - \Delta_T + \Delta_N)y_b] + (2q_r - 1)(\Delta_N - \Delta_T)(b + \alpha) > 0$, which is equivalent to

$$y_b > \hat{y}_b \equiv \frac{(\Delta_T - \Delta_N)[(2q_r - 1)(\bar{b} + \alpha) - \delta y_a]}{\delta(\Delta p^S - \Delta_T + \Delta_N)} = \frac{(\Delta_N - \Delta_T)\bar{y}_b^P}{\delta(\Delta p^S + \Delta_N - \Delta_T)}, \tag{24}$$

given that $\Delta p^S - \Delta_T + \Delta_N = p_T^S - \Delta_T - (p_N^S + \Delta_N) > 0$. Suppose first that $\Delta_T \geq \Delta_N$. Then $\hat{y}_b \leq 0$ because $\bar{y}_b^P > 0$ and thus (24) is satisfied; in this case, providing the licensing opportunity relaxes the constraint $b \leq \bar{b}$ and therefore reduces the brain drain. Suppose now that $\Delta_T < \Delta_N$. Then $0 < \hat{y}_b < \bar{y}_b^P$ and the licensing opportunity reduces the brain drain if and only if $\hat{y}_b \leq y_b < \bar{y}_b^P$.

(ii) The proof is straightforward and is omitted.

Proof of Proposition 5

(i) As we have mentioned after introducing SW^S, we obtain $m_T^e = \Pi_T + 2\gamma\varphi_T - \gamma + \alpha p_T^R - \alpha\beta_T$, $m_N^e = \Pi_N + 2\gamma\varphi_N - \gamma + \alpha p_N^R - \alpha\beta_N$ from (14)-(15) and plug them into SW^S. In this way we obtain a concave function of (g_G, g_B), and thus the first order conditions (16)-(17) are necessary and sufficient for maximization.

(ii) Since p_T^S and p_N^S are concave [by assumption 5(ii)], which means that $\frac{dp_T^S}{dg}$ and $\frac{dp_N^S}{dg}$ are decreasing, it is straightforward to see from (16)-(17) that g_G^* and g_B^* are decreasing in k. Thus, m_T^{e*} and m_N^{e*} are increasing in k.

(iii) We find that $\frac{\partial k}{\partial \alpha} < 0$, $\frac{\partial k}{\partial q_r} < 0$ and $\frac{\partial k}{\partial \lambda} = \frac{s^H - s^L - \alpha(2q_r - 1)}{(s^H - s^L + \alpha\lambda(2q_r - 1))^2}$; $\frac{\partial k}{\partial \lambda} > 0$ since $s^H - s^L > \alpha$.

Proof of Proposition 6

We notice that (18) is positive if and only if $\varphi_T < \varphi_N + \frac{\alpha}{2\gamma}(\beta_T - \beta_N - \Delta p^R)$. We prove below that $\beta_T - \beta_N > (2q_r - 1)\Delta \underline{p}^S$, thus $\varphi_T \leq \varphi_N + \Phi$ implies that (18) is positive. Finally, $\Phi > 0$ if and only if $q_r > \underline{q}_r$. In order to prove that $\beta_T - \beta_N > (2q_r - 1)\Delta \underline{p}^S$, we use (12)-(13):

$$\begin{aligned}
\beta_T - \beta_N &= (2q_r - 1)\left[q_s p_T^S(g_G^*) + (1 - q_s)p_T^S(g_B^*) - q_s p_N^S(g_B^*) - (1 - q_s)p_N^S(g_G^*)\right] \\
&= (2q_r - 1)\left[p_T^S(g_B^*) - p_N^S(g_B^*) + \int_{g_B^*}^{g_G^*}\left(q_s\frac{dp_T^S(g)}{dg} - (1 - q_s)\frac{dp_N^S(g)}{dg}\right)dg\right] \\
&> (2q_r - 1)[p_T^S(g_B^*) - p_N^S(g_B^*)] \geq (2q_r - 1)[p_T^S(\underline{g}) - p_N^S(\underline{g})] = (2q_r - 1)\Delta \underline{p}^S
\end{aligned}$$

where the two inequalities hold because of assumption 5 and $q_s > \frac{1}{2}$.

References

ACEMOGLU D., T. VERDIER (1998), "Property rights, corruption and the allocation of talent: a general equilibrium approach", *Economic Journal*, 108, pp. 1381-1403.

ACEMOGLU D., T. VERDIER (2000), "The choice between market failures and corruption", *American Economic Review*, 90, pp. 194-211.

ADAMS J.D., G.C. BLACK, J.R. CLEMMONS, P.E. STEPHAN (2005), "Scientific teams and institutional collaborations: evidence from U.S. universities, 1981-1999", *Research Policy*, 34, pp. 259-285.

AGHION P., E. COHEN (2004), *Education et Croissance*, La Documentation Française, Paris.

AGHION P., M. DEWATRIPONT, J.C. STEIN (2005), Academic freedom, private-sector focus, and the process of innovation, NBER Working Paper 11542.

BENABOU R., J. TIROLE (2006), "Incentives and prosocial behavior", *American Economic Review*, 96, pp. 1652-1678.

BESLEY T., M. GHATAK (2005), "Competition and incentives with motivated agents", *American Economic Review*, 95, pp. 616-636.

BUTZ W., G. BLOOM, M. GROSS, K. KELLY, A. KOFNER, H. RIPPEN (2003), "Is there a shortage of scientists and engineers? How would we know?", Rand Issue Paper 241.

CASELLI F. (1999), "Technological revolutions", *American Economic Review*, 89, pp. 78-102.

COHEN W., R. FLORIDA, L. RANDAZZESE, J. WALSH (1998), "Industry and the academy: uneasy partners in the cause of technological advance" In: R. Noll (Ed.), *Challenges to Research Universities*, Brookings Institution Press, Washington, D.C., pp. 171-199.

DASGUPTA P., P.A. DAVID (1987), "Information disclosure and the economics of science and technology" In: G.R. Feiwel (Ed.), *Arrow and the Ascent of Modern Economic Theory*, New York University Press, New York, pp. 519-542.

DASGUPTA P., P.A. DAVID (1994), "Toward a new economics of science", *Research Policy*, 23, pp. 487-521.

DEWATRIPONT M., V. GINSBURGH, P. LEGROS, A. WALCKIERS (2006), Study on the Economic and Technical Evolution of the Scientific Publication Markets in Europe. Available at the website http://ec.europa.eu/research/science-society/pdf/scientific-publication-study_en.pdf.

EDLIN A., N. EDLIN, D.L. RUBINFELD (2004), "Exclusion or efficient pricing: the 'big deal' bundling of academic journals", *Antitrust Law Journal*, 72, pp. 119-157.

EHRENBERG R.G. (1991), "Academic labor supply" In: C. Clotfelter, R. Ehrenberg, M. Getz, J. Siegfried (Eds.), *Economic Challenges in Higher Education*, University of Chicago Press, Chicago, pp. 143-258.

EUROPEAN COMMISSION (2003), Executive summary and conclusions of the project "Brain drain – emigration flows for qualified scientists". Available at the website http://ec.europa.eu/research/era/pdf/indicators/merit_exsum.pdf.

FLORIDA R. (1999), "The role of the university: leveraging talent, not technology", *Issues in Science and Technology*, 15, pp. 67-73.

GROSSMAN G. (2004), "The distribution of talent and the pattern and consequences of international trade", *Journal of Political Economy*, 112, pp. 209-239.

GROSSMAN G., G. MAGGI (2000), "Diversity and trade", *American Economic Review*, 90, pp. 1255-1275.

GUESNERIE R., J.-J. LAFFONT (1984), «A complete solution to a class of principal-agent problems with an application to the control of a self-managed firm", *Journal of Public Economics*, 25, pp. 329-369.

JEON D.-S., J.-J. LAFFONT (1999), "The efficient mechanism for downsizing the public sector", *World Bank Economic Review*, 13, pp. 67-88.

JEON D.-S., J.-J. LAFFONT (2006), "Labor market information acquisition and downsizing", *Review of Development Economics*, 10, pp. 345-364.

JEON D.-S., D. MENICUCCI (2006), "Bundling electronic journals and competition among publishers", *Journal of the European Economic Association*, 4, pp. 1038-1083.

KWOK V., H. LELAND (1982), "An economic model of the brain drain", *American Economic Review*, 72, pp. 91-100.

Kremer M. (1993), "The O-ring theory of economic development", *Quarterly Journal of Economics,* 108, pp. 551-575.

Laffont J.-J., J. Tirole (1993), *A Theory of Incentives in Procurement and Regulation*, MIT Press, Cambridge.

Lazear E.P. (2005), "Entrepreneurship", *Journal of Labor Economics*, 23, pp. 649-680.

Levin S., P. Stephan (1991), "Research productivity over the life cycle: evidence from American scientists", *American Economic Review*, 81, pp. 114-132.

Merton R.K. (1957), "Priorities in scientific discovery: a chapter in the sociology of science", *American Sociological Review*, 22, pp. 639-659.

Merton R.K. (1968), "Behavior patterns of scientists", *American Scientist*, 58, pp. 1-23. Reprinted In: R.K. Merton (1973), *The Sociology of Science: Theoretical and Empirical Investigations*, University of Chicago Press, Chicago, pp. 325-341.

Merton R.K. (1973), *The Sociology of Science: Theoretical and Empirical Investigations*, University of Chicago Press, Chicago.

Murphy K.J. (1999), "Executive compensation" In: O. Ashenfelter, D. Card (Eds.), *Handbook of Labor Economics*, Vol. IIIB, Elsevier, Amsterdam, pp. 2485-2563.

Murphy K., A. Shleifer, R.W. Vishny (1991), "The allocation of talent: the implications for growth", *Quarterly Journal of Economics*, 106, pp. 503-530.

National Science Board (2004), Science and Engineering Indicators. Available at the website http://www.nsf.gov/statistics/seind04/pdfstart.htm.

New York Times (2004), "National Science PanelWarns of Far Too Few New Scientists", May 5, page A24.

New York Times (2005), "Doesn't Anyone Want to Manage Harvard's Money?", August 5, page C1.

Perotti R. (2002), The Italian university system: rules vs. incentives, Available at the website http://www.igier.uni-bocconi.it/whos.php?vedi = 1653&tbn = albero&id_folder = 177.

Rochet J.-C., L. Stole (2002), "Nonlinear pricing with random participation", *Review of Economic Studies*, 69, pp. 277-311.

Rosen S. (1981), "The economics of superstars", *American Economic Review*, 71, pp. 845-858.

Rosenberg N. (2004), Science and technology: which way does the causation run?, Available at the website http://www.crei.cat/activities/sc_conferences/23/papers/rosenberg.pdf.

Stephan P.E. (1996), "The economics of science", *Journal of Economic Literature*, 34, pp. 1199-1235.

Stokes D. (1997), *Pasteur's Quadrant*, Brookings Institution Press, Washington, D.C.

Stigler G.J. (1988), *Memoirs of an Unregulated Economist*, Basic Books, New York.

Thursby J.G., M.C. Thursby (2003), "Patterns of research and licensing activity of science and engineering faculty" In: R. Ehrenberg, P. Stephan (Eds.), *Science and the University*, University of Wisconsin Press, Madison, forthcoming.

Wall Street Journal Europe (2004),"The Brain drain", September 3, page R1.

Zumeta W., J.S. Raveling (2002), The best and brightest for science: is there a problem here?, Commission on Professional in Science and Technology (CPST), Washington.

Incentives, sorting and productivity along the career: Evidence from a sample of top economists

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Summary

In this paper we study empirically the labor market of economists. We look at the mobility and promotion patterns of a sample of 1000 top economists over thirty years and link it to their productivity and other personal characteristics. We find that the probability of promotion and of upward mobility is positively related to past production. However, the sensitivity of promotion and mobility to production diminishes with experience, indicating the presence of a learning process. We also find evidence that economists respond to incentives. They tend to exert more effort at the beginning of their career when dynamic incentives are important. This finding is robust to the introduction of tenure, which has an additional negative ex post impact on production. Our results indicate therefore that both promotions and tenure have an effect on the provision of incentives. Finally, we detect evidence of a sorting process, as the more productive individuals are allocated to the higher ranked universities.

1. Introduction

The provision of incentives in firms is a fundamental issue in economics. Standard theory suggests the use of formal explicit incentives that tie the wage or the reward of the agent to his performance and thus align the objectives of the agent to those of the principal. These formal static incentives discourage the agent to cheat or lie about private information since this behavior would result in decreasing his own utility. Common applications among others are piece rate schemes, bonuses and stock options.

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Despite the presumed efficiency of explicit incentives, the use of pay based on performance is not widespread but limited to some specific jobs such as chain workers or top executives. Moreover, some empirical facts – such as the weak elasticity of pay to performance and the small share that CEOs hold in their firm – do not fit well with the incentive theory. The limited use of wages tied to performance and the questions raised about their purpose seem to indicate that – in the real world – formal explicit incentives are not that important and that other aspects also matter.

First, there are dimensions that economists have neglected and which can completely change the predictions about the use of output-based pay: relationship between an individual and a firm are often repeated interactions and must be analyzed in a dynamic framework; relationships can be broken and individuals' behavior is influenced by their outside options. Theories on careers shed some light on the way these dimensions affect the behavior of individuals: repeated interactions facilitate learning about the agent's talent by observing noisy signals, can provide a solution to the moral hazard problem, and also help to achieve an efficient allocation of workers either within or between firms. Second, there are other mechanisms than performance pay widespread in firms. Among others, promotions and the way wages are determined inside the firm can also have important consequences on the behavior of individuals.

This paper studies these issues in the academic labor market using data on the career and productivity of a sample of top economists. While most studies interested in testing the effect of performance on pay or career evolution have difficulties finding individual productivity data (see e.g. Lazear, 2000), the advantage of taking top economists as an object of study is that information about research productivity is available through bibliographic databases such as Econlit. Moreover, it is relatively easy to relate research performance with the personal characteristics and career path of the agents. Economists usually post their CVs on their personal web site, from which we could extract personal information such as promotion years and years of experience. Additionally, jobs along the hierarchy are easily identifiable and standard across "firms".

The first subset of the literature on careers that we consider for our analysis relies on symmetric learning. Individuals differ with respect to their ability to perform on the job, and employers have no informational advantage over other firms when learning about the individuals' ability (e.g. Jovanovic, 1979; Gibbons and Katz, 1992). These models generate the following testable predictions. First, career outcomes depend on observed past performance, as the market assesses the talent of individuals based on their achievements. Second, the value of new information diminishes with experience. The market updates its belief after every time period and the estimation becomes more accurate with time. Third, learning gives rise to a sorting process, as individuals are reallocated across firms over their career. Fourth, the probability of separation between a worker and his firm decreases with experience, as the learning becomes more accurate.

Additional interesting predictions can also be obtained by integrating other theories to the learning model. The introduction of incentives aspects in the learning model points out the effect that careers can have on the behavior of agents. Holmström (1982) shows that individuals can be motivated by career concerns: by exerting effort, they influence the market's belief about their ability, what improves their career prospects. His main finding is that incentives decrease along the career: as the market gives less weight to new information, agents react by exerting less effort [2]. Multiperiod tournament theory (Rosen, 1986) and learning also predict a decline of effort along the career but only after the last promotion (Lazear, 2004). Finally, Gibbons and Waldman (1999a) add job assignment and on-the-job human capital acquisition to learning. Their model implies that individual productivity increases with experience and rank. In the academic labor market, job assignment could be seen as less crucial than in firms, as individuals do the same job in all ranks [3], while learning and human capital acquisition are likely to be as important.

Another strand of the literature studies the case where the firm employing the worker learns more accurately about the worker's ability than the market. In these models of asymmetric learning (Waldman, 1984; Greenwald, 1986; Bernhardt, 1995), job assignment provides a signal about ability to the market what attenuates asymmetric information. It would seem that asymmetric learning would be less important in academia, as individual productivity on the main task of the job is public knowledge. On the other hand, Waldman (1990) explains the existence of up-or-out contracts (a prevalent feature of the academic labor market) using a model based on asymmetric learning and investment in general human capital [4]. One way to reconcile these two ideas is to consider that some aspects of individuals' performance are not observed by the market (e.g. positive externalities on colleagues' research, quality of teaching) and that there is asymmetric learning on these factors. Under the additional assumption that firms value talent differently (or if ability is multi-dimensional; see Greenwald, 1986, p. 336), the following prediction arises: the asymmetry of information impedes turnover and the assignment of workers reduces the asymmetry of information regarding a workers's ability. Therefore, turnover should increase after a promotion [5].

We link career patterns of economists to their productivity and evaluate how the sensitivity of promotion and mobility to productivity evolves with experience and with academic positions. This allows us to test implications from symmetric and asymmetric learning, with or without incentives, and human capital theories. We also analyze the dynamics of individual productivity along the career, testing whether faculty exert less effort for research after being promoted. Finally, we study whether mobility leads to sorting of individuals across universities.

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[2] Another effect is that young managers may be tempted – if they are risk averse – to engage in herding behavior so as to avoid to give a wrong signal about their talent to the market in the beginning of their career (Scharfstein and Stein, 1990). This herding behavior due to career concerns has been a major concern of papers investigating empirically implicit incentives in financial activities. We do not consider this issue here.

[3] Different universities could put different weights on the different tasks that individuals have to perform at each layer. We discuss further the implications of multitasking for our analysis.

[4] Other theories of up-or-out contracts are based on the assumption of firm specific human capital acquisition, which does not seem to be the case in academia (e.g. Kahn and Huberman, 1988).

[5] The signalling aspect of promotions provides incentives to workers (Zabojnik and Bernhardt, 2001) and the level of effort is higher at the beginning of the career (Ghosh and Waldman, 2004), as in the career concern model.

We find that the probability of promotion increases with experience, as predicted by human capital theory. The probability of promotion is also positively related to past performance and the sensitivity of promotion to performance diminishes with experience. We get a similar finding for upward mobility: the change in quality of the institution when an economist switches university depends on his performance and performance becomes less important for mobility as the individual becomes more experienced. We find that turnover does not increase after a promotion, rejecting the signalling role that promotions could have according to asymmetric learning models. These findings rather support implications from symmetric learning models about ability. We also find that effort is higher at the beginning of the career. This finding is robust to the introduction of tenure, which has an additional negative ex post impact on production. We interpret the fact that effort decreases along the career as evidence of dynamic incentives and discuss alternative explanations for this result. Moreover, we detect the presence of a sorting process as the more productive individuals are allocated to the more productive universities. Finally, productivity also increases with experience, although at a decreasing rate, in line with human capital theory. Our findings therefore suggest that symmetric learning, human capital and dynamic incentives theories explain to a large extent careers in our sample.

Our empirical analysis is related to three different existing literatures. The first one has designed various tests to study learning and career concerns theories. Gibbons and Murphy (1992) test whether CEO wages are more sensitive to performance as individuals come closer to retirement. Their results confirm this hypothesis, what is consistent with the idea that static incentives should be more important when dynamic incentives become weaker. Chevalier and Ellison (1999) show that mutual fund manager's probability of separation with his employer is negatively related to performance and that separation is more performance sensitive for young managers. Similar results are found by Hong *et al.* (2000) for security analysts [6]. We extend the literature by analyzing learning and dynamic incentives in the academic profession. Learning about individual ability through publication should play an important role in explaining promotion patterns within departments. Moreover, we do not only focus on mobility along the hierarchy of the firm but also look at mobility across firms, as our database allows us to track people when they leave the firm.

Another recent literature has analyzed individual career paths in a firm's internal labor market where workers are shielded from the outside [7]. Empirical work so far has been limited to a small amount of studies describing the internal labor market of a single firm (starting with Lazear, 1992 and Baker, Gibbs and Holmström, 1994a,b [8])

[6] Hong and Kubik (2003) look at upward and downward mobility. They find that more (less) accurate analysts are more likely to experience a move to a more (less) prestigious firm.

[7] The pioneer work is due to Doeringer and Piore (1971). The central idea is that the internal organization of the firm is shielded from the outside. As consequence, the hierarchy remains stable over time and workers follow well-established career paths; wages are more attached to jobs than individuals; and firms restrict movements between the inside and the outside labor market to a limited number of jobs (there exist ports of entry and exit in the job structure).

[8] More recent examples are Dohmen *et al.* (2004) who study careers in a declining firm and Lima and Pereira (2003) using career data from a sample of Portuguese firms. See also Gibbs and Hendricks (2004) and the studies referenced therein.

that have documented the existence of a learning process about ability [9]. While our sample does not contain the entire population of a given firm, it allows us not only to look at careers *inside* firms but also *between* firms, as already discussed.

We also contribute to the small literature studying the effect of research productivity on mobility in the academic labor market (Ault *et al.*, 1979, 1982; Long, 1978; Allison and Long, 1987). These studies typically find no or a small effect of productivity on upward mobility, and document instead a pedigree effect on promotion and a departmental effect on productivity. However, these studies consider only individuals who change university, and therefore do not treat the mobility decision as endogenous. Moreover, they do not consider promotions explicitly. We use a large sample of top economists and analyze the relationship between performance and both university change and promotion, explicitly linking our results to the theories of incentives, learning and human capital acquisition.

The rest of the paper is organized as follows. Section 2 describes our dataset and provides summary statistics. In Section 3, we analyze the promotion decision. In Section 4, we turn to the mobility issue. In Section 5, we look at the dynamics of productivity along the career. Section 6 concludes.

2. Data

Our dataset is created by combining various sources. The first one is the bibliographic database EconLit. EconLit keeps record of all publications from 1969 onwards in the most important journals of the profession [10]. The publication is linked to each author, who is linked (since 1990) to the university to which he is affiliated at the time when the paper was accepted. We extracted the entire information contained in the 2000 version of EconLit and aggregated publications by year and by individual. One interesting and very important feature of this dataset is that we are able to follow the individual productivity of economists and of universities on a year-by-year basis, that we will use as measure of individual *performance* in terms of research.

The dataset can also be used to create a worldwide ranking of individuals over a given period. All rankings are typically criticized for the subset of journals that they consider and how a publication is weighted depending on the quality of the journal where it was published. There is a large dose of subjectivity associated with these choices. To deal with this criticism, we have selected 12 different weighting techniques which have been widely used in the literature (described in Appendix A), and we have used the average of the rankings based on these 12 measures to determine an average ranking of individuals (see Coupé, 2000). We also follow the literature by correcting the weight of a publication for coauthorship, dividing the weight of the paper by the number of authors. Using this technique, we identified the 1000 top economists for the period 1987-1998.

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[9] While they confirm the presence of a stable hierarchy over a long period of time, and the existence of careers inside the firm, they do not find much evidence of ports of entry and exit, and mixed evidence that wages are attached to jobs. Evidence from learning is further confirmed by the finding that wages and promotions are serially correlated, the latest being evidence of systematic fast tracks. See also Baker and Holmström (1995).

[10] In the period 1969-2000, some 800 journals have been indexed by Econlit. About 10 % of these have been included every year since 1969.

As a second step, we collected information about the career of these 1000 top economists by downloading their vitae from their personal web site.

We kept only those individuals for whom we could clearly identify the entire career since the year of Ph.D. This was the case for *652 individuals*. Economists post their vitae homogeneously and we were able to find the year of Ph.D., the university of Ph.D., the rank, the employer and the year of promotion. However, we faced two difficulties. First, very few economists indicated the year when tenure was awarded, despite the importance of this information, especially on the North American market. Second, research represents only one of the tasks for which economists have to exert effort, the others being teaching, administrative and editorial duties, and possibly consulting.

Therefore, in March and April 2003, we sent a survey by email to ask about the year of tenure, but also about the number of teaching hours in the first and second term of the academic year 2002-2003 [11]. These questions were only relevant for individuals having an academic position. The answers regarding the year of tenure can be used in our dynamic econometric analysis. This is not the case for the teaching information. We received 415 answers, implying an answer rate of more than 60 %, a very satisfactory figure.

Finally, the career information from the web search and the survey were matched to the publication information from EconLit.

A. *Sample description*

Most of the economists in our sample work in the U.S.: in 1998, 530 out of 650 (two had died before the end of the period) were affiliated to an institution in the U.S., 76 in Europe, 22 in Canada, 11 in Asia, 8 in Israel, 2 in South America and 1 in Australia. There are only 33 women.

By definition, our sample is not representative of the whole population of economists. We do not try to generalize our results to the economic profession. We concentrate our attention on top researchers because it was easier to find information about these individuals and because top researchers were likely to have interesting mobility patterns.

Our sample also differs from the internal labor market literature as we do not focus on one single firm, but rather compare career paths of individuals in a labor market where talent can be argued to be hardly firm specific and where firms value the same skills. There are pros and cons of this approach. A big advantage is that we follow individuals when they leave the firm, and that we know the past employment history of the individual, even outside the firm. A disadvantage is that we only have a limited sample of individuals, as opposed to the entire population of a firm [12].

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[11] We also ask questions about the amount of consulting but due to the lack of homogeneity in the way the answers were reported, we were unable to use them.

[12] In a companion paper, we use information of a *cross-sectio*n of the entire population of individuals working in the 107 economic departments ranked by the NRC in 1995 to test which theory is the best suited to explain the wage structure along the hierarchy. We are not able to use the wage data in the present paper because they are aggregated by rank and thus not suited for a study of individual careers.

Table 1 Summary statistics

Variable	*# obs.*	*# of ind.*	*Mean*	*Standard deviation*	*Min*	*Max*
Experience	12038	652	11.59	8.93	0	57
Assistant professor	12038	652	0.22	0.42	0	1
Associate professor	12038	652	0.17	0.38	0	1
Full professor	12038	652	0.39	0.49	0	1
Endowed professor	12038	652	0.16	0.36	0	1
Out of academe	12038	652	0.06	0.23	0	1
Category	10540	620	4.76	1.49	1	7
PROM	10716	620	0.11	0.31	0	1
UCH	10716	620	0.07	0.25	0	1
UP	10568	620	0.02	0.14	0	1
DOWN	10568	620	0.02	0.15	0	1
EVEN	10568	620	0.01	0.12	0	1
DCAT	9769	620	– 0.01	0.47	– 5	5
# OF PUBLICATIONS WEIGHTED BY THE IMPACT FACTOR						
Current performance						
Performance in t	12038	652	1.34	1.60	0	21.53
Short run past performance						
Performance from $t-3$ to $t-1$	11632	652	3.74	3.49	0	48.86
Performance from $t-1$ to $t+1$ (controlling for publication lag)	11207	652	4.03	3.43	0	48.86
Long run past performance						
Performance from 1969 to $t-1$	11386	652	15.53	17.38	0	179.42
Performance from 1969 to $t+1$ (controlling for publication lap)	11386	652	16.91	17.79	0	181.90
# OF PUBLICATIONS WEIGHTED BY THE LP CORRECTED IMPACT FACTOR						
Current performance						
Performance in t	12038	652	0.29	0.35	0	4.74
Short run past performance						
Performance from $t-3$ to $t-1$	11632	652	0.81	0.76	0	10.41
Performance from $t-1$ to $t+1$ (controlling for publication lag)	11207	652	0.87	0.75	0	10.41
Long run past performance						
Performance from 1969 to $t-1$	11386	652	3.50	3.83	0	38.53
Performance from 1969 to $t+1$ (controlling for publication lap)	11386	652	3.79	3.91	0	38.61

Table 1 provides the summary statistics about the dependent and independent variables used in our analysis. Experience is defined as the number of years since an individual obtained his Ph.D. The mean level of experience is 11.6 years. However, there is a considerable amount of heterogeneity in our sample: in 1998, three individuals had more than 50 years of experience and are still considered in our sample, while five have only 5 years of experience and are already considered in our sample (see Table 2).

Table 2 Number of individuals by number of years of experience in 1998

	Nr. of ind.	*%*
EXP < 11	105	16.15%
10 < EXP < 21	324	49.85%
20 < EXP < 31	158	24.31%
30 < EXP < 41	49	7.54%
40 < EXP < 51	11	1.69%
EXP > 50	3	0.46%

B. Current and past research productivity

To control for the quality of the publications, various schemes have been proposed in the literature [13]. We indicated already that we selected 12 different methods to select our individuals. However, in our econometric analysis, we use only a subset of these measures. The more objective and also most frequently used way to judge the quality of a publication is based on the expected citations of a paper published in a given journal. The first measure is the number of publications weighted by the impact factor of the journal. The impact factor is equal to the citations in year t to the articles published in journal J in $t-1$ and $t-2$ divided by the number of articles published in J in $t-1$ and $t-2$. This reflects the number of citations that can be expected for an article published in J, measured one to two years after publication. This impact factor is available for 273 journals and made available on CD Rom.

However, this method has been criticized based on the fact that many non economic journals are present in the database and that the hierarchy based on reputation is not respected [14]. Therefore, we also use the adjusted impact methodology proposed by Laband and Piette (1994). Their index is based on 4 years of data (1990 citations to articles published between 1985 and 1989) and considers only economic journals in a stricter sense. The disadvantage is that this adjusted index is only available for 121 journals. We divide the Laband and Piette (LP) adjusted index by 100 for ease of interpretation. Our results are robust to the different weighting schemes used.

On average, economists in our sample publish the equivalent of 0.57 article by year in the *Journal of Political Economy* (JPE) according to the impact factor weight

[13] We decided not to use citations as an additional variable because we could not identify the number of citations per year but only the stock of citations at the end of the period, i.e. between the year of publication and 1998.

[14] This is less likely for our subset of economists since they were selected as the most productive based on 12 different weighting schemes.

(0.52 according to the LP corrected impact factor weight). However, the most prolific scholars were able to publish the equivalent of 9 papers in the JPE (Samuelson in 1974 and Feldstein in 1976) in a given year.

In our econometric analysis, we want to assess whether research productivity affects internal and external mobility and if learning occurs, so we need a measure of past productivity [15]. We use two different measures of performance in $t - 1$: a short run past performance and a long run past performance. The first one is the sum of weighted past publications for a period of three years, from year $t - 3$ to $t - 1$. The second is the past cumulative history of the individual, i.e. the sum of weighted publications from 1969 to $t - 1$.

C. *Job categories and promotions*

According to the information provided on the CV, we define 5 different job categories, 4 of them being related to the academic world. Based on the U.S. system, assistant professor is noted as 1, associate professor as 2, professor as 3 and endowed professors as 4. We applied an equivalence rule for the non-U.S. institutions, although most non-U.S. economists tended to indicate the U.S. equivalent on their CV. Category 5 includes individuals working outside the university sector (central banks, private firms and international institutions). This is another specificity of our dataset and of the academic profession: jobs are easily defined and standardized across universities. Table 1 shows that assistant professors account for 22 % of our observations, associate professors for 17 %, full professors for 39 % and endowed professors for 16 %, while 6 % of our observations consists of individuals who were outside academia. However, these figures are varying over the period, and at the end of our dataset, most people have reached the rank of full professor, while almost all individuals have occupied the rank of assistant professor and associate professor. Appendix B provides the number of assistant, associate, full and endowed professors by year. The number of assistant professors reached a peak in 1986 with 173 individuals, the number of associate professors reaching a maximum in 1992, while the number of professors and endowed professors has kept on increasing.

We define a promotion as an upward switch within the university system (from category 1 to 4). We observe 1156 promotions over the period. The most frequent types of promotions are hierarchical: 465 are promotions from assistant to associate professor, 406 from associate to full professor and 196 from professor to endowed professor [16].

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[15] It is not clear whether it is important to lag our productivity measures because of the well recognized publication lag that changes the timing of observing research productivity. While the market is likely to evaluate individuals on the basis of their CVs, forthcoming publications are also taken into account for promotions and job offers. We used two alternative measures to control for publication lags. Our short run past performance variable controlling for publication gap is the sum of weighted past publications from year $t - 1$ to $t + 1$ and the long run past performance variable controlling for publication gap is the sum of weighted publications from 1969 to $t + 1$. Results using these variables were similar to those shown in the paper.

[16] It is not very clear whether we should consider the latter type of promotion in our analysis because not all universities have endowed chairs. All our results are unchanged if we do not allow a switch from professor to endowed professor as a promotion. Therefore, we stick with our classification.

Individuals differ with respect to the number of years that they spend in a given position before being promoted. For all the individuals who were promoted to associate professor, the number of years as assistant professor varies between 1 and 12 years, with a mean of 4.72. For all individuals who were promoted to professor, the average number of years spent as associate professor is 4.05 and varies from 1 to 14.

D. Tenure

Promotions constitute an important component of incentives provided in universities, as they are accompanied typically by wage and status increase. When put in practice (standard procedure in North America, rare in Europe), the tenure decision provides further incentives to work hard [17]. Tenure implies almost complete job security but is a relatively difficult hurdle to beat.

Out of 415 answers, 16 economists were out of academe and 8 had tenure before getting their Ph.D. (7 of them in Europe, 1 in Asia). Summary statistics are based on the 391 more standard answers. The average time before getting tenure is 5.86 years. However, there are large differences in our sample, even among economists in the same department.

Tenure is awarded at different stages of the career. In many universities, it goes automatically with the promotion from assistant to associate professor. Others take more time to select individuals and wait a few years after that. In general, the higher the quality of the university, the latter in the career comes the tenure decision.

E. Teaching

Unfortunately, we are not able to use the information about teaching behavior in our econometric analysis, because it refers to the academic year 2002-2003, while our period of analysis goes until 1998. We expected that the answer rate would be smaller if we asked retrospective questions about teaching. Nevertheless, we try to gain insight about teaching that we could link to our results. On average, individuals were teaching 2.95 hours per week during the first term and 3.23 during the second. Most individuals who answered the survey have become professor (206) or endowed professor (174) in 2003, while 15 are still associate, 2 assistant and 2 emeritus. Therefore, we only have limited information about the evolution of teaching along the career. Teaching tends to diminish along the career in the sample, going from 3.97 hours a week as associate to 3.16 as professor and 2.98 as endowed professor. Teaching also appears to be lower in the higher ranked universities. However, there are no large differences between countries.

F. University categories and research productivity

The individuals are linked to their employer. The quality of university research is measured in different ways. For the period 1990-1998, we aggregate individual publications by university, and we follow the same strategy than for individuals to create a ranking of universities, i.e. considering the average of our 12 weighting schemes. The problem is that we would like to be able to assess the quality of

[17] For a theoretical explanation of the existence of tenure, see e.g. Carmichael (1988).

university research before 1990, what is not possible using EconLit. Therefore, we selected a sensible ranking that is compatible with previous rankings. For earlier periods, we use Niemi (1975) for the period 1970-1974, Graves *et al.* (1982) for the period 1974-1978, Hirsch *et al.* (1984) for the period 1978-1982, and Scott and Mitias (1996) for the period 1983-1994. These studies have the advantage that they are comparable but relatively selective. These rankings consider the number of pages in the same 24 top journals [18], except the ranking by Scott and Mitias based on 36 journals (of which 21 similar to the other studies), for different time periods and are corrected for differences in page size. While the number of pages is unlikely to be related to the quality of the paper, the main advantage is that we are able to follow the dynamics of the rankings, or, in other words, to have a time-varying assessment of the quality of the departments.

One disadvantage is that these papers only ranked U.S. universities, except Hirsch *et al.* (1984). This means that for the early periods before 1990, we are not able to identify very precisely upward or downward moves from one European university to another. This is a minor difficulty because of the high percentage of individuals working in the U.S., but we should keep it in mind for the interpretation and representativeness of the results. Another criticism against this ranking is that they are biased in favor of universities that have strong research oriented business schools, as it is difficult to distinguish between business school economists and economic departments economists. To properly address this concern, one would need the *evolutio*n of the composition of economic departments, but we were not able to obtain this information. Moreover, many top economists are affiliated to both the business school and the economic department in their university.

Table 3 shows the evolution of rankings and university production over a relatively long period, from 1970 to 1998 for the top 20 departments. Some stylized facts emerge from the data: Chicago and Harvard have persistently remained at the top, while more dynamics is present among the followers. Production on a 5-year period appeared to have increased for the top departments. Following this pattern, we divide universities in seven different categories: the top 2 (category 7, Chicago and Harvard), the close contenders (category 6, those ranked between 3rd and 9th), the contenders (category 5, between the 10th and the 24th position), the upper middle ranked (category 4, those ranked between 25th ad 49th), the lower middle ranked (category 3, between the 50th and the 100th), the low ranked (category 2, between the 100th and 300th position) and the very low ranked (category 1, those under the 300th position).

[18] *American Economic Review, Econometrica, Economica, Economic Development and Cultural Change, Economic Journal, Industrial and Labor Relations Review, International Economic Review, Journal of Business, Journal of Economic History, Journal of Economic Theory, Journal of Finance, Journal of Human Resources, Journal of Law and Economics, Journal of Money, Credit and Banking, Journal of Political Economy, Journal of Regional Science, Journal of the American Statistical Association, National Tax Journal, Oxford Economic Papers, Quarterly Journal of Economics, Review of Economics Studies, Review of Economics and Statistics, Southern Economic Journal, Western Economic Journal (Economic Inquiry).*

Table 3 Production and ranking of the top 20 research departments in economics

Rank	*University*	*1970-1974*	*Rank*	*University*	*1974-1978*	*Rank*	*University*	*1978-1983*
1	Harvard	2273	1	Chicago	2248	1	Chicago	2976
2	Chicago	1603	2	Harvard	2007	2	Harvard	2427
3	Yale	1354	3	Stanford	1747	3	Stanford	1996
4	Wisconsin	1278	4	Wisconsin	1349	4	Pennsylvania	1660
5	Stanford	1201	5	Pennsylvania	1287	5	Yale	1503
6	MIT	1115	6	MIT	1089	6	Northwestern	1462
7	Pennsylvania	1090	7	Yale	978	7	MIT	1442
8	Princeton	1052	8	UCLA	959	8	Wisconsin	1386
9	Berkeley	995	9	Berkeley	947	9	Berkeley	1281
10	UCLA	871	10	Princeton	891	10	UCLA	1246
11	Carnegie-Mellon	854	11	Northwestern	859	11	Cornell	1237
12	Michigan	841	12	Michigan	768	12	Columbia	1229
13	Northwestern	824	13	Washington-Seattle	704	13	Princeton	1187
14	Washington-Seattle	807	14	Rochester	693	14	Minnesota	1124
15	Rochester	725	15	Illinois-Urbana	688	15	Michigan	1062
16	Minnesota	675	16	North Carolina	686	16	Rochester	984
17	Illinois	594	17	Columbia	681	17	Illinois-Urbana	941
18	Brown	575	18	NYU	674	18	NYU	901
19	SUNY-Buffalo	548	19	Ohio State	621	19	Carnegie-Mellon	901
20	Michigan State	533	20	Minnesota	609	20	Washington-Seattle	878

Rank	*University*	*1984-1993*	*Rank*	*University*	*1990-1994*	*Rank*	*University*	*1994-1998*
1	Harvard	6867	1	Chicago	2974	1	Harvard	3481
2	Chicago	6767	2	Harvard	2814	2	Chicago	3055
3	Pennsylvania	5735	3	Northwestern	2398	3	MIT	2310
4	MIT	5388	4	Pennsylvania	2274	4	Pennsylvania	2291
5	Northwestern	5176	5	MIT	2172	5	Northwestern	1987
6	Stanford	4972	6	Stanford	1984	6	Stanford	1791
7	Princeton	4434	7	Michigan	1796	7	UCLA	1680
8	Michigan	3868	8	UCLA	1747	8	Berkeley	1556
9	Berkeley	3863	9	Yale	1630	9	NYU	1526
10	UCLA	3806	10	Princeton	1606	10	Michigan	1483
11	Yale	3574	11	Berkeley	1580	11	Yale	1382
12	Columbia	3539	12	Columbia	1424	12	Princeton	1346
13	NYU	2732	13	NYU	1317	13	Cornell	1214
14	Rochester	2718	14	Duke	1216	14	Columbia	1181
15	Wisconsin	2643	15	Cornell	1152	15	Wisconsin	1073
16	Carnegie-Mellon	2613	16	Rochester	1089	16	Duke	891
17	Cornell	2602	17	Wisconsin	1064	17	UCSD	880
18	Duke	2558	18	LSE	1045	18	Ohio State	870
19	Illinois-Urbana	2366	19	Ohio State	962	19	LSE	859
20	Minnesota	2101	20	Illinois-Urbana	944	20	Minnesota	807

Source: Niemi (1975), Graves *et al.* (1982), Hirsch *et al.* (1984), Scott and Mitias (1996) and Coupé (2000).

G. *Individual mobility*

While internal labor market considerations are an important aspect of the academic labor market, another contribution of the paper is that we also consider the external labor market, i.e. the mobility from one university to another. Mobility can be driven either by the individual looking for a better employment opportunity, or by the firm, which could consider that the individual is not a good "match" and therefore does not want to keep him.

University changes occur more rarely than promotions: the average university change rate is 6.7 %. Table 4 provides the distribution of the number of university change by individuals along their career. Some move a lot: 19 individuals moved more than three times during their career. The university change rate varies along the hierarchy: full professor in particular move much less than assistant and associates (Table 5).

Table 4 The proportion of movers

		% people	*# people*
number of moves	0	28.7	176
	1	39.6	243
	2	22.7	139
	3	5.9	36
	4	2.0	12
	5	1.0	6
	6	0.1	1
			613

Table 5 Probability of university change by rank

Rank	*# obs.*	*probability of university change*
assistant professor	2655	10.9%
associate professor	1972	9.8%
professor	4337	4.1%
endowed professor	1672	3.6%

We decompose outside mobility as going upward, downward or to a similar university. We define an upward move (*UP*) as a move to a university of a higher category, a downward move (*DOWN*) as a move to a university of a lower category, and a neutral move (*EVEN*) as a move to a university of the same category. The distinction can only be made when the category of the university is known. On average, we find roughly the same rate of upward and downward mobility (2 %). The rate of neutral moves is slightly lower (around 1.4 %). We also construct a more informative variable of mobility by looking at the difference between the category in t and the category in $t-1$ (*DCAT*).

The internal and external labor markets explanations might be related, as an individual can accept a place at a university with a lower reputation if he gets a promotion. We therefore computed the percentage of university changes that go together with a rank change and vice versa: 27 % of promotions are accompanied by a change of university; 44 % of university changes are accompanied by a promotion. Promotion is more likely for associate professors changing universities (61 %) than for assistant professors (54 %), and professors (24 %).

3. Determinants of promotions

We analyze whether career outcomes inside the firm, i.e. promotions, depend on past performance and if the sensitivity of promotions to productivity evolves through time. The purpose of this test is to see if there is a learning process about individual talent by the firm and how the assessment of talent evolves through time. Furthermore, firms could also promote individuals if they have accumulated enough human capital, so we also look at the effect of experience on the probability of promotion.

We first regress the probability of promotion on past performance and past performance interacted with experience. We do not consider individuals who have reached the last level of the hierarchy since they are no longer concerned with promotions. Therefore, our analysis only uses a subset of our observations, i.e. those individual-year observations before reaching the last layer. We consider two different cases: one with endowed professors as the last layer of the hierarchy; and another with full professors as the last step of the career ladder (see footnote 15).

We use two definitions of past productivity: a short run past performance (the sum of weighted past publications for a period of three years, from year $t-3$ to $t-1$) and a long run past performance (the past cumulative history of the individual, i.e. the sum of weighted publications from 1969 to $t-1$). Moreover, we consider two different measures of productivity: publications weighted by the impact factor and weighted by the LP corrected impact factor (see previous section for a discussion regarding the measures of performance). We use experience (EXP_{it}) and experience squared ($EXPSQ_{it}$) to take into account human capital accumulation. We also add a dummy for the position before the change $POS_{i(t-1)}$. When we consider all promotions, we include a dummy for assistant professor and for associate professor, while we only need a dummy for assistant professors when we restrict our analysis to the promotions to associate and to full professor. α_5 is therefore a vector of parameters for the position dummies. We run the following probit regression:

$$PROM^*_{it} = \alpha_0 + \alpha_1 PERF_{i(t-1)} + \alpha_2 PERF_{i(t-1)} EXP_{it} + \alpha_3 EXP_{it} \tag{1}$$

$$+ \alpha 4 EXPSQ_{it} + \alpha_5 POS_{i(t-1)} + \varepsilon_{it}$$

$$\text{where } PROM_{it} = 1 \text{ if } PROM^*_{it} > 0$$

$$PROM_{it} = 0 \text{ if } PROM^*_{it} \leq 0$$

In order to see how the assessment of productivity evolves as the individual goes up the ladder, we also interact the productivity variables with the type of promotion instead of experience. We therefore run a similar probit regression:

$$PROM^*_{it} = \alpha'_0 + \alpha'_1 PERF_{i(t-1)} + \alpha'_2 PERF_{it-1} POS_{i(t-1)} + \alpha'_3 EXP_{it} + \alpha'_4 EXPSQ_{it} + \alpha'_5 POS_{i(t-1)} + \varepsilon'_{it} \quad (2)$$

where α'_2 is the vector of parameters for the interacted variables.

According to theory, productivity should have a larger effect on the probability of promotion at the beginning of the career. In the estimation of Eq.(1), we expect a positive sign for α_1 and a negative sign for α_2, indicating that production matters for promotion but that new information becomes less important with time. Similarly, in the estimation in Eq.(2), the effect of productivity should be more important for promotion from assistant professor to associate professor, than for promotion from associate professor to full professor, and the least effect should be for promotions from full professor to endowed professor.

Table 6A Effect of performance on promotion (probit estimation) – Articles weighted by the impact factor

Dep. var.: PROM$_{it}$	*Short run past performance*				*Long run past performance*			
	all promotions		*only promotions to asso. and prof.*		*all promotions*		*only promotions to asso. and prof.*	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
PERF$_{i(t-1)}$	0.021*** (0.002)	0.005*** (0.001)	0.035*** (0.005)	0.020*** (0.003)	0.008*** (0.001)	0.0015*** (0.0004)	0.028*** (0.003)	0.013*** (0.002)
PERF$_{i(t-1)}$*EXP$_{it}$	– 0.0008*** (0.0001)	-	– 0.0015*** (0.0007)	-	– 0.0003*** (0.00005)	-	– 0.0016*** (0.0003)	-
PERF$_{i(t-1)}$*ASST$_{i(t-1)}$	-	0.019*** (0.003)	-	0.013*** (0.004)	-	0.013*** (0.001)	-	0.010*** (0.003)
PERF$_{i(t-1)}$*ASSOC$_{i(t-1)}$	-	0.008*** (0.002)	-	-	-	0.007*** (0.001)	-	-
ASST$_{i(t-1)}$	0.477*** (0.022)	0.330** (0.028)	0.181*** (0.013)	0.135*** (0.021)	0.486*** (0.022)	0.276*** (0.026)	0.191*** (0.013)	0.130*** (0.022)
ASSOC$_{i(t-1)}$	0.330*** (0.018)	0.253* (0.025)	-	-	0.369*** (0.018)	0.182*** (0.025)	-	-
EXP$_{it}$	0.032*** (0.002)	0.028*** (0.002)	0.086*** (0.006)	0.079*** (0.006)	0.024*** (0.002)	0.022** (0.002)	0.073*** (0.006)	0.072*** (0.006)
EXPSQ$_{it}$	– 0.0007*** (0.0001)	– 0.0007*** (0.0001)	– 0.003*** (0.0003)	– 0.003*** (0.0003)	– 0.0005*** (0.0001)	– 0.0006*** (0.0001)	– 0.002*** (0.0004)	– 0.003*** (0.0003)
Nr. Obs.	8714	8714	4495	4495	8959	8959	4641	4641
Log likelihood	– 2856.31	– 2842.66	– 2006.51	– 2004.17	– 2993.33	– 2954.31	– 2088.18	– 2089.57
Pseudo R^2	0.14	0.15	0.12	0.12	0.13	0.14	0.11	0.11

Note: marginal changes; standard errors in parentheses; ***/**/* denote resp. significance at 1%/5%/10%.

Table 6B Effect of performance on promotion (probit estimation) – Articles weighted by the corrected LP impact factor

Dep. var.: $PROM_{it}$	*Short run past performance*				*Long run past performance*			
	all promotions		*only promotions to asso. and prof.*		*all promotions*		*only promotions to asso. and prof.*	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
$PERF_{i(t-1)}$	0.092*** (0.008)	0.026*** (0.006)	0.157*** (0.021)	0.084*** (0.013)	0.035*** (0.004)	0.008*** (0.002)	0.123*** (0.014)	0.052*** (0.007)
$PERF_{i(t-1)}$*EXP_{it}	– 0.004*** (0.001)	-	– 0.008*** (0.003)	-	– 0.001*** (0.0002)	-	– 0.007*** (0.002)	-
$PERF_{i(t-1)}$*$ASST_{i(t-1)}$	-	0.083*** (0.011)	-	0.060*** (0.019)	-	0.056*** (0.006)	-	0.048*** (0.012)
$PERF_{i(t-1)}$*$ASSOC_{i(t-1)}$	-	0.031*** (0.011)	-	-	-	0.028*** (0.005)	-	-
$ASST_{i(t-1)}$	0.477*** (0.022)	0.338*** (0.028)	0.181*** (0.013)	0.134*** (0.021)	0.489*** (0.022)	0.286*** (0.027)	0.192*** (0.013)	0.128*** (0.021)
$ASSOC_{i(t-1)}$	0.329*** (0.018)	0.265*** (0.025)	-	-	0.370*** (0.018)	0.197*** (0.026)	-	-
EXP_{it}	0.032*** (0.002)	0.028*** (0.002)	0.088*** (0.006)	0.081*** (0.006)	0.024*** (0.002)	0.022** (0.002)	0.073*** (0.006)	0.074*** (0.006)
$EXPSQ_{it}$	– 0.0007*** (0.0001)	– 0.0007*** (0.0001)	– 0.003*** (0.0003)	– 0.003*** (0.0003)	– 0.0005*** (0.0001)	– 0.0007*** (0.0001)	– 0.002*** (0.0004)	– 0.003*** (0.0003)
Nr. Obs.	8714	8714	4495	4495	8959	8959	4641	4641
Log likelihood	– 2856.91	– 2844.18	– 2007.82	– 2005.80	– 2990.53	– 2957.65	– 2088.93	– 2091.54
Pseudo R^2	0.14	0.15	0.12	0.12	0.13	0.14	0.11	0.11

Note: marginal changes; standard errors in parentheses; ***/**/* denote resp. significance at 1%/5%/10%.

Results are provided in Tables 6A (using impact factor weights) and 6B (using LP corrected impact factor weights), where we report the marginal changes and not the coefficients of the probit regressions. We start with estimating Eq.(1) using short run past performance (column 1). We observe that production is positively related to the likelihood of promotion. Moreover, production interacted with experience has a negative effect: this appears to indicate that performance becomes less informative on the talent of the agent as he becomes more experienced. This result can not be explained by a "ceiling effect" (i.e. there is a limited amount of promotions in academia and most individuals reach the last stage) because we only consider individuals who are still candidates for promotion and do not consider individuals who have reached the last layer of the hierarchy in our analysis. Our results are still valid when we only consider the promotions to associate and to full professor (column 3).

We also see that human capital accumulation partly explains promotions: experience has a positive effect on the probability of promotion but the sensitivity of promotion to experience decreases with time. We also control for the position before the promotion occurred. The likelihood to be promoted is higher at the stage of assistant professor than at the stage of associate professor. Using rank dummies controls for the fact that this promotion occurs more often in the sample, as already indicated by the summary statistics. This might be related to the fact that departments are limited in the amount of time that they can wait to delay the promotion (by the nature of up-or-out contracts). Similar results are obtained using long run past performance (columns 5 and 7).

When estimating Eq.(2), using short run past performance (column 2), we obtain similar conclusions: the likelihood of being promoted is more related to performance in the earlier stages of an individual's career. Performance is more informative when little is known about the talent of the agent, but is still informative for the promotion from professor to endowed professor. Again, using long run past performance (column 6) and only considering the first two promotions (columns 4 and 8) does not change our results [19].

These results suggest the existence of a learning process inside the firm about the agent's ability through time, as predicted by learning theories, either with or without incentives considerations. Human capital also plays a role as the level of experience partly determines the probability of being promoted.

4. Determinants of mobility

While the previous section studied the assessment of ability within the firm, we focus in this section on the learning process of the external labor market. We look at the mobility decision and consider different types of university change depending on university quality. Under the assumption of symmetric learning, upward mobility should become more likely if individuals have been more productive in the past, and the sensitivity of upward mobility should diminish with experience as the agent's ability becomes better estimated by the market. Research performance is publicly observable and outside firms have no informational disadvantage in that dimension. However, firms could also care about other dimensions of ability, which are only observable by the employer, and other firms could then consider promotion as a signal about the ability of the agent in these other dimensions. Therefore, we can test one implication from asymmetric learning that turnover increases after a promotion. Finally, we also check whether mobility diminishes with experience, as suggested by matching theory.

We use three different measures for our explanatory variable. Our first specification analyzes the probability of upward mobility (*UP*), i.e. the probability that an individual moves to a higher ranked university. Universities were grouped into 7 categories according to their quality of research. An upward move means a move to a higher category of university (the way we computed these measures is described in

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[19] We also used duration analysis to look at the determinants of the duration of a stay in a given rank. We used a discrete time proportional hazard model (Prentice and Gloecker, 1978) and obtained similar results.

Section 2). Individuals in category 7 were not considered in our analysis as they can not move to a more prestigious university [20].

We look at the effect of past performance on upward change and whether the sensitivity of upward change to performance decreases with experience. We use both short run and long run past performance as before. We also add experience (EXP_{it}) and experience squared ($EXPSQ_{it}$) and the category of the university where the individual was before the move ($CAT_{i(t-1)}$). We run the following probit regression:

$$UP^*_{it} = \gamma_0 + \gamma_1 PERF_{i(t-1)} + \gamma_2 PERF_{i(t-1)} * EXP_{it} + \gamma_3 EXP_{it} + \gamma_4 EXPSQ_{it} + \gamma_5 CAT_{i(t-1)} + \eta_{it} \tag{3}$$

$$\text{where } UP_{it} = 1 \text{ if } UP^*_{it} > 0$$

$$UP_{it} = 0 \text{ if } UP^*_{it} \leq 0$$

In our second specification, we test whether the probability of a downward move (*DOWN*), i.e. the probability to move to a lower ranked university, is negatively related to past performance [21]. Individuals in the lowest category were not used in this regression as they can not experience downward moves. We run a similar probit regression:

$$DOWN^*_{it} = \gamma'_0 + \gamma'_1 PERF_{i(t-1)} + \gamma'_2 PERF_{i(t-1)} * EXP_{it} + \gamma'_3 EXP_{it} + \gamma'_4 EXPSQ_{it} + \gamma'_5 \mathrm{CAT}_{i(t-1)} + \eta'_{it} \tag{4}$$

$$\text{where } DOWN_{it} = 1 \text{ if } DOWN^*_{it} > 0$$

$$DOWN_{it} = 0 \text{ if } DOWN^*_{it} \leq 0$$

In a third specification, we consider a more precisely defined variable for the difference in quality: the change in the category of university (*DCAT*) as defined in Section 2. We run in that case an ordered probit regression:

$$DCAT_{it} = \gamma''_0 + \gamma''_1 PERF_{i(t-1)} + \gamma''_2 PERF_{i(t-1)} * EXP_{it} + \gamma''_3 EXP_{it} + \gamma''_4 EXPSQ_{it} + \gamma''_5 \mathrm{CAT}_{i(t-1)} + \eta'_{it} \tag{5}$$

Results are provided in Table 7, using performance weighted by the impact factor. We first look at the estimations using long run past performance (the first three columns). The estimates of Eq. (3) show that past performance has a positive but small effect on the probability of moving upwards and that the sensitivity of upward mobility to past performance decreases with experience. As we expected, results for downward mobility (Eq. (4)) are reversed: past performance has a negative effect on the probability of going to a less prestigious university, but the effect becomes less important with experience. When analyzing the change in category

[20] As opposed to our analysis of promotions, we include here individuals who have reached the last layer of the hierarchy, as they could still experience a move to more prestigious universities. In other words, there is no "ceiling effect" regarding inter-university mobility.

[21] This variable is close to the termination variable used in Chevalier and Ellison (1999).

(Eq. (5)), we find once again that production explains mobility, but less as experience increases. In line with the matching theory, we also see that the likelihood of mobility decreases with experience in the estimations of Eq. (3) and (5), although at a decreasing rate. Finally, we see that previous category has a negative sign in the estimation of Eq. (3) and (5) and a positive sign in Eq. (4), meaning that upward mobility is more difficult to achieve. We obtained similar results using the performance weighted by the LP corrected impact factor.

Table 7 Effect of performance on upward and downward mobility (probit and ordered probit estimation) Articles weighted by the impact factor

Dep. var.:	*Long run past performance*			*Short run past performance*		
	UP_{it}	*$DOWN_{it}$*	*$DCAT_{it}$*	*UP_{it}*	*$DOWN_{it}$*	*$DCAT_{it}$*
	(probit)		*(ordered probit)*	*(probit)*		*(ordered probit)*
$PERF_{i(t-1)}$	0.0012*** (0.0004)	– 0.0007** (0.0003)	0.0154*** (0.0031)	0.0019*** (0.0007)	0.0016** (0.0007)	0.0105 (0.0080)
$PERF_{i(t-1)}*EXP_{it}$	– 0.000032* (0.00002)	0.000025* (0.00001)	– 0.0004*** (0.0001)	– 0.00001 (0.00004)	– 0.0001** (0.0001)	0.0004 (0.0005)
EXP_{it}	– 0.0031*** (0.0008)	0.00022 (0.0007)	– 0.0316*** (0.007)	– 0.0020*** (0.0006)	– 0.0008 (0.0005)	– 0.0125** (0.0052)
$EXPSQ_{it}$	0.000055* (0.00003)	– 0.000047* (0.00003)	0.0009*** (0.0002)	0.00002 (0.00002)	0.000002 (0.00002)	0.0003** (0.0001)
$CATE_{i(t-1)}$	– 0.0092*** (0.001)	0.0083*** (0.001)	– 0.184*** (0.011)	– 0.0090*** (0.0010)	0.0076*** (0.0010)	– 0.1782*** (0.0114)
Nr. Obs.	8615	9601	9769	8442	9395	9556
Log likelihood	– 938.42	– 1010.29	– 4499.59	– 928.00	– 984.25	– 4454.23
Pseudo R^2	0.06	0.06	0.03	0.05	0.05	0.03

Note: marginal changes for the probit regression, coefficients for the ordered probit; standard errors in parentheses; ***/**/* denote resp. significance at 1%/5%/10%.

We performed the same estimations using short run past performance (the three last columns of Table 7). The results are unclear and it seems that the measure of short run past performance is less able to capture the effect of learning that we had found in the previous section. This could indicate that, in the case of mobility, learning occurs only via long run past performance and not via a short term measure. This contrasts with the analysis of promotions where both definitions reveal the existence of a learning process.

These findings appear to suggest that the market – as the firm – learns about individual ability. The information provided by the performance of the agent becomes less valuable as he gains experience and as the market evaluates the talent more precisely. As in the previous section, these results are in line with symmetric learning theories with or without incentives, but contradict the assumption of asymmetric learning models that other firms are unable to observe individuals' performance since research performance is publicly observable. However, it might still be the case that the market learns only about some dimensions of the agent's ability, but not on others, and still suffers from an informational disadvantage on these other dimensions.

To assess the importance of asymmetric learning models in our analysis, we run an additional test and check whether the probability of turnover increases after promotion [22]. We do not find evidence supporting that prediction (see Appendix C). Associate professors do not differ from assistant professors in terms of mobility, and both experience more turnover than full professors [23]. This goes against the prediction of asymmetric learning models that promotions play a signalling role, at least in our sample of top economists.

5. The dynamics of productivity

In this section, we use our data on individual performance to assess which theories of careers can explain the dynamics of productivity. Following human capital theory (Becker, 1962; Ben-Porath, 1967), productivity should increase along the career as individuals accumulate more skills. Learning theories also predict that productivity would rise with rank if more talented individuals are allocated to jobs where their talent is more valuable. However, as already discussed, job assignment does not seem to be an issue in academia. Models of learning that include incentives considerations have as an additional prediction that effort declines along the career.

To test these theories, we regress the production of individuals on the rank, the category of university where the economist works, experience and experience squared. To control for the publication lag, we lag the individual rank and the category of the university by two years.

$$\begin{aligned} PERF_{it} &= \alpha_0 + \alpha_1 ASST_{i(t-2)} + \alpha_2 ASSOC_{i(t-2)} + \alpha_3 PROF_{i(t-2)} \\ &+ \alpha_4 EXP_{it} + \alpha_5 EXPSQ_{it} + \sum_{j=2}^{7} \beta_j CAT_{ij(t-2)} + \varepsilon_{it} \qquad (6) \end{aligned}$$

As before, we use two different measures of performance: the publication in year t weighted by the impact factor and the publications in year t weighted by the LP corrected impact factor. CAT_{ij} is a dummy equal to 1 if the individual i works in a university of category j and 0 otherwise.

Our analysis so far has stressed the importance of the learning process about agents' ability. As this suggests that one component of productivity is the talent of the individual, the latter might be correlated with the rank and the category of university of the individual. Therefore, we allow for unobserved heterogeneity (υ_i), which might be correlated with our explanatory variables ($\varepsilon_{it} = \upsilon_i + \xi_{it}$, $\xi_{it} \sim N(0,\sigma^2)$) and use a fixed effect model.

[22] We thank one anonymous referee for suggesting this additional test.

[23] However, the high mobility of assistant professors could also be due to up-or-out contracts, as those who did not get tenure should experience a downward move. To control for this, we ran separate estimations according to the type of mobility. For both downward and upward mobility, we found a pattern similar to the one we observed under turnover, i.e. there is no difference in mobility patterns between assistant and associate professors, while turnover decreases once the stage of full professor is attained.

Our specification assumes that there are five components to productivity: pure talent to publish, effort for research, an "on-the-job" human capital acquisition component, an externality component and a noise. Talent is represented by the fixed effect. We use rank dummies to test the idea that effort is declining along the career. To distinguish this strategic effect from aging effect, we control for on-the-job human capital acquisition by adding experience and experience squared. Externality is represented by the university category dummies and represents how the quality of the university affects individual performance. Finally, there is pure noise representing luck.

We first estimate Eq. (6) using simple OLS. Results are presented in the first and the third column of Table 8 (respectively with the impact factor and the LP corrected impact factor). Performance appears to go up as one goes up the ladder, and individuals in more prestigious universities tend to produce more. However, these results might be biased due to the presence of unobserved heterogeneity.

Table 8 Determinants of productivity

Dep. var.:	*Articles weighted by*			
	the impact factor		*the corrected LP impact factor*	
	(1)	(2)	(3)	(4)
	OLS	*Fixed Effect*	*OLS*	*Fixed effect*
$ASST_{i(t-2)}$	– 0.589*** (0.085)	0.475*** (0.108)	– 0.132*** (0.019)	0.106*** (0.024)
$ASSOC_{i(t-2)}$	– 0.449*** (0.073)	0.370*** (0.089)	– 0.096*** (0.016)	0.087*** (0.020)
$PROF_{i(t-2)}$	– 0.152*** (0.054)	0.158** (0.067)	0.025** (0.012)	0.047*** (0.015)
Category $2_{i(t-2)}$	0.074 (0.142)	– 0.072 (0.198)	0.041 (0.031)	0.012 (0.044)
Category $3_{i(t-2)}$	0.108 (0.136)	– 0.022 (0.200)	0.050* (0.030)	0.020 (0.044)
Category $4_{i(t-2)}$	0.355*** (0.132)	0.056 (0.202)	0.109*** (0.029)	0.028 (0.045)
Category $5_{i(t-2)}$	0.455*** (0.131)	0.061 (0.203)	0.129*** (0.029)	0.026 (0.045)
Category $6_{i(t-2)}$	0.732*** (0.131)	0.063 (0.206)	0.175*** (0.029)	0.024 (0.046)
Category $7_{i(t-2)}$	0.965*** (0.136)	0.157 (0.222)	0.243*** (0.030)	0.058 (0.049)
EXP_{it}	– 0.049*** (0.009)	0.032*** (0.010)	– 0.015*** (0.002)	0.002 (0.002)
$EXPSQ_{it}$	0.001*** (0.0001)	– 0.001*** (0.0002)	0.0002*** (0.00004)	– 0.0003*** (0.00005)
Constant	1.679*** (0.164)	1.046*** (0.228)	0.369*** (0.036)	0.255*** (0.051)
Adj.R^2 Nr.Obs.	0.036 9325	0.203 9325	0.036 9325	0.189 9325

Note: standard errors in parentheses, ***/**/* denote resp. significance at 1%/5%/10%.

Results from the fixed effect estimation are shown in columns 2 and 4 of Table 8. First, we see that both the coefficients of assistant and of associate professors are positive and significant, suggesting that controlling for unobservable fixed characteristics, pre-promoted economists have higher production than the post-promoted ones. This supports the prediction that effort is higher in the beginning of the career. Moreover, the coefficient of assistant professor is larger than the coefficient of associate professor, which itself is larger than the coefficient of full professor (the control group is endowed professors; similar results apply if full professors form the control group). We discuss below other potential explanations of this result, in particular the reallocation of tasks along the career, as other aspects of the job like refereeing, editing and advising may become more important as individuals become more experienced. Second, the results also provide evidence of an efficient sorting: the category variable is no longer significant, what indicates that the more performing scholars are allocated to the more productive universities [24]. Third, production increases with experience, but at a decreasing rate, in line with human capital theory. The estimates also show that after around 30 years, experience no longer positively affects productivity, due to human capital depreciation. To sum up, our results are in line with predictions of learning theory with incentives and on-the-job human capital acquisition.

Alternative explanations

1. *Serial correlation of errors*

Despite the fact that we use fixed effect estimation, the error structure might still exhibit serial correlation ($\xi_{it} = \rho\xi_{i(t-1)} + v_{it}$, $v_{it} \sim N(0,\sigma^2)$) that could bias our results. To control for this possibility, we used a fixed effect model with potential AR(1) disturbance (Bhargava *et al.*, 1982). Results are reported in Table 9. The null hypothesis that errors are serially independent is rejected (the modified Bhargava *et al*. Durbin-Watson being 1.92). Note however that the estimated ρ is small and equal to 0.046 under both measures of performances. We see that allowing for potential serial correlation does not change the results: our findings are similar to the ones of the fixed effect estimation.

2. *Sample composition*

We checked whether our results could be explained by the composition of our sample. Indeed, an alternative explanation could be that individuals who are still assistant or associate professors in 1998 are also more productive on average because they are included in the sample, despite the fact that they have been present on the market during a shorter period. To control for this possibility, we only used data for those individuals who had become professors before 1998 and found similar results.

[24] In addition of using category dummies, we also used the category itself, university dummies and the productivity of the university (as presented in Table 3). Using the latter variable, we found evidence of an externality effect: university productivity in $t - 2$ had a positive effect on individual productivity, indicating that being at a better university increases productivity prospects. The effect was smaller in the fixed effect regression than in the OLS regression, suggesting that sorting was still present.

Table 9 Determinants of productivity – Controlling for serial correlations of errors

Dep. var.:	*Fixed effects models with potential AR(1) disturbance (Bhargava* et al.*, 1982)*	
	Articles weighted by	
	the impact factor	*the corrected LP impact factor*
$ASST_{i(t-2)}$	0.435*** (0.116)	0.092*** (0.026)
$ASSOC_{i(t-2)}$	0.319*** (0.096)	0.072*** (0.021)
$PROF_{i(t-2)}$	0.149** (0.071)	0.042*** (0.0158)
Category $2_{i(t-2)}$	– 0.013 (0.223)	0.026 (0.049)
Category $3_{i(t-2)}$	– 0.005 (0.228)	0.022 (0.051)
Category $4_{i(t-2)}$	0.116 (0.231)	0.043 (0.051)
Category $5_{i(t-2)}$	0.106 (0.231)	0.038 (0.051)
Category $6_{i(t-2)}$	0.135 (0.235)	0.044 (0.052)
Category $7_{i(t-2)}$	0.168 (0.253)	0.064 (0.056)
EXP_{it}	0.015 (0.011)	-0.002 (0.002)
$EXPSQ_{it}$	– 0.001*** (0.0003)	– 0.0002*** (0.0001)
Constant	1.190*** (0.247)	0.293*** (0.055)
ρ	0.046	0.046
Modified Bhargava *et al.* Durbin-Watson	1.915	1.915
Baltagi-Wu LBI	2.050	2.046
R^2 within	0.02	0.03
R^2 between	0.05	0.06
Nr.Obs.	8686	8686

Note: standard errors in parentheses, ***/**/* denote resp. significance at 1%/5%/10%.

3. *Multitasking*

There could be an alternative explanation for our results linked to the multitasking nature of the academic activity. Research output only represents one aspect of the academic job and other activities – as teaching, administrative duties, editorial work, consulting, and political activities have to be taken into account. Effort for research could diminish because effort increases (relatively) for the other tasks. Our sample of top economists are employed in institutions that emphasize research. Regarding teaching, our summary statistics using current cross sectional information suggest that the teaching load diminishes along the career [25]. Therefore, it can not be the case that differences in the number of teaching hours are an explanation for the decline of effort along the career. This is not necessarily true for the other activities, such as administrative, advising, refereeing and editorial tasks. Despite our best efforts, it was impossible to obtain homogeneous retrospective information about these tasks.

This alternative explanation, which raises the issue of the optimal allocation of tasks along the career for academic scientists, is not necessarily substitute but rather complement to the existence of learning and dynamic incentives. This reallocation of tasks is more likely to take place when information about talent is more precise, i.e. when people have been promoted professor. In our results, effort for research declines gradually along the career, while the other explanation would predict a sharp decline at the end of the career.

4. Tenure

Tenure is an important component of academic life, especially on the North American labor market, where it is awarded only when the university considers having the right match with the candidate. The tenure system has important consequences on the sorting of individuals and can also have a negative ex post disincentive effect similar to a promotion. As some have pointed out, tenure is probably the most important promotion in academic life. Therefore, we adapt the methodology of the previous section to test the effect of tenure on production. Moreover, adding tenure as an additional variable allows us to test the robustness of our previous results. The equation to be estimated is similar to Eq. (6) with the exception that a dummy variable TEN_i is added, equal to 1 if the individual i was tenured in $t-2$ and 0 otherwise:

$$PERF_{it} = \alpha'_0 + \alpha'_1 TEN_{i(t-2)} + \alpha'_2 ASST_{i(t-2)} + \alpha'_3 ASSOC_{i(t-2)} + \alpha'_4 PROF_{i(t-2)} + \alpha'_5 EXP_{it} + \alpha'_6 EXPSQ_{it} + \sum_{j=2}^{7} \beta'_j CAT_{ij(t-2)} + \varepsilon_{it} \tag{7}$$

Results in Table 10 are comparable to those of Table 8. Therefore, our previous results are robust when we add the effect of tenure. Effort is still decreasing along the career, suggesting that promotions still have an incentive effect, even when controlling for the existence of tenure. We see however that the difference in the coefficients between assistant an associate professors has been reduced, which suggests that part of the reduction of incentives for associate professors is due to the fact that many of them are tenured. Indeed, we find the unsurprising result that tenure has an additional negative effect.

[25] Siow (1995a) also discusses the fact that incentives to spend time on research diminishes along the career, as research productivity declines with age while the opposite is true for teaching. In a companion paper, he finds weak evidence of this pattern: the number of hours spent in teaching and administration is not significantly affected by age. However, he finds some evidence that “beside age considerations, universities systematically trade research for teaching and administration for tenured faculty” (Siow, 1995b, p. 24).

Table 10 Determinants of productivity – Controlling for tenure

Dep. var.:	*Articles weighted by*			
	the impact factor		*the corrected LP impact factor*	
	(1)	(2)	(3)	(4)
	OLS	*Fixed Effect*	*OLS*	*Fixed effect*
$TEN_{i(t-2)}$	0.095 (0.083)	– 0.186*** (0.093)	0.024 (0.018)	– 0.037* (0.021)
$ASST_{i(t-2)}$	– 0.411*** (0.117)	0.350** (0.148)	– 0.107*** (0.026)	0.080*** (0.033)
$ASSOC_{i(t-2)}$	– 0.379*** (0.087)	0.330*** (0.108)	– 0.089*** (0.019)	0.079*** (0.024)
$PROF_{i(t-2)}$	– 0.228*** (0.063)	0.107 (0.080)	– 0.040*** (0.014)	0.036** (0.018)
Category $2_{i(t-2)}$	– 0.053 (0.167)	0.019 (0.237)	0.018 (0.037)	0.027 (0.053)
Category $3_{i(t-2)}$	– 0.031 (0.159)	0.023 (0.241)	0.023 (0.035)	0.026 (0.054)
Category $4_{i(t-2)}$	0.225 (0.157)	0.096 (0.242)	0.084** (0.035)	0.036 (0.054)
Category $5_{i(t-2)}$	0.349** (0.155)	0.104 (0.244)	0.111*** (0.034)	0.029 (0.055)
Category $6_{i(t-2)}$	0.584*** (0.156)	0.129 (0.249)	0.150*** (0.034)	0.034 (0.055)
Category $7_{i(t-2)}$	0.768*** (0.164)	0.187 (0.275)	0.212*** (0.036)	0.048 (0.061)
EXP_{it}	– 0.040*** (0.013)	0.047*** (0.015)	– 0.015*** (0.003)	0.005 (0.003)
$EXPSQ_{it}$	0.0007** (0.0003)	– 0.001*** (0.0004)	0.0003*** (0.00006)	– 0.0003*** (0.0001)
Constant	1.628 (0.207)	0.984*** (0.290)	0.373*** (0.046)	0.244*** (0.065)
Adj.R^2 Nr.Obs.	0.03 5784	0.15 5784	0.03 5784	0.15 5784

Note: standard errors in parentheses, ***/**/* denote resp. significance at 1%/5%/10%.

6. Conclusion

In this paper, we have analyzed the careers of a sample of top economists by linking promotion and upward mobility to research productivity. We have found evidence that production was positively related to promotion and upward mobility, but also that the effect of productivity on career outcomes was decreasing with experience. We have also found that effort is higher at the beginning of the career when incentives are stronger. Sorting and matching appear to play an important role as well: over the career, individuals are allocated to universities according to their respective productivity.

We have discussed alternative explanations for our results. We have shown that neither potential serial correlation of errors nor sample composition lead to biases in our results. We have also checked whether our findings were the consequence of the tenure decision. What we interpret as a decreasing effort along the career could simply be a reflection of the ex post disincentive effect of tenure. We therefore added tenure as an additional explanatory variable in our analysis. We found that, even if tenure has a negative effect on the level of effort, it can not explain the decreasing pattern we observe along the career. Finally, another alternative explanation is linked to the multitasking nature of the work in the academic world: effort for research could decline along the career because incentives to spend time for other activities increase. Existing research and our summary statistics do not suggest that teaching load increases along the career, but this might not be the case for the time spent for other tasks like administration and editing work. Unfortunately, we were not able to obtain homogeneous and retrospective information about work for these tasks. However, prestigious and time consuming editor or chairman positions are more likely to be awarded after the promotion to professor, when talent is more precisely known. This would suggest that effort for research would decline only at this stage while we find a gradual decline along the career. This explanation might nevertheless be complement to ours as both theories predict a decline of effort for research, although at a different stage of the career.

The lack of performance data is often considered as an important limitation of studies analyzing careers in organizations. One of the main contribution of our paper is that we have a precise measure of individual productivity on the most important aspect of the job of top economists, i.e. research. This allows us to study how organizations use observed performance to learn about individuals' talent and how individuals react to this learning process.

Our approach is also complementary to previous work on internal labor markets. While these papers only consider careers inside firms, we also take into account external mobility in the career path of workers. We introduce explicitly heterogeneity between firms in our empirical analysis and we show that individuals are reallocated across firms as a consequence of learning by the market. This offers a new perspective on careers and stresses the importance of integrating turnover into the existing internal labor market literature.

Appendix A

List of different weighting techniques

1: Number of articles (unweighted).

2: Number of articles weighted by the impact factor (see Section 2 for a definition).

3: Number of pages weighted by the Bauwens index (a publication is assigned a weight between one and five on the basis of the product of the impact factor and the total number of citations received during a given year and a weight of 1 to journals not included in the Journal Citation Report but included in Econlit).

4: Number of articles weighted by the Laband and Piette corrected impact factor (see Section 2 for a definition).

5: Number of articles weighted by the Laband and Piette corrected impact factor, adjusted for page size.

6: Number of pages (unweighted).

7: Number of pages, weights based on Laband and Piette.

8: Number of pages, weights based on Laband and Piette, adjusted for page differences.

9: Number of pages published in the a subset of ten top journals (*American Economic Review*, *Econometrica*, *Journal of Political Economy*, *Journal of Monetary Economics*, *Review of Economic Studies*, *Quarterly Journal of Economics*, *Journal of Economic Theory*, *Review of Economics and Statistics*, *Economic Journal*, *European Economic Review*) weighted by the LP corrected impact factor.

10: Number of pages published in a subset of ten top journals weighted by the LP corrected impact factor, corrected for the size of the paper.

11: Number of pages, weights based on Niemi, 1975, Graves, Marchand and Thompson, 1982 and Hirsch, Austin, Brooks and Moore, 1984.

12: Number of pages, weights based on Scott and Mitias, 1996.

Appendix B

Evolution of the number of individuals per year (by position)

Year	*Number of assistant prof.*	*Number of associate prof.*	*Number of full prof.*	*Number of endowed prof.*
1969	30	13	27	3
1970	31	18	34	3
1971	37	18	38	3
1972	45	21	39	6
1973	54	24	42	8
1974	60	28	51	9
1975	63	34	55	11
1976	69	41	59	13
1977	70	42	69	14
1978	77	48	75	19
1979	92	45	85	21
1980	96	52	90	28
1981	115	58	103	26
1982	119	69	111	31
1983	132	72	124	37
1984	146	76	131	42
1985	156	76	149	48
1986	173	83	161	54
1987	165	91	189	65
1988	160	101	207	75
1989	150	110	225	84
1990	143	110	240	91
1991	129	120	248	101
1992	110	122	266	113
1993	94	116	275	129
1994	67	116	287	142
1995	42	112	302	157
1996	30	95	320	171
1997	16	87	325	187
1998	7	69	338	199

Appendix C

Effect of performance on turnover (probit estimation)

Articles weighted by the impact factor

Dep. var.:	*Long run past performance University Change$_{it}$*	*Short run past performance University Change$_{it}$*
$PERF_{i(t-1)}$	0.0011** (0.006)	0.0047*** (0.0119)
$PERF_{i(t-1)}$*EXP_{it}	– 0.00003 (0.00003)	– 0.0001* (0.0001)
EXP_{it}	0.0001 (0.0015)	0.0012 (0.0013)
$EXPSQ_{it}$	– 0.0001 (0.0001)	– 0.0001* (0.00003)
$CATE_{i(t-1)}$	– 0.004*** (0.0015)	– 0.0046*** (0.0016)
$ASST_{i(t-1)}$	0.041*** (0.0157)	0.0453*** (0.157)
$ASSOC_{i(t-1)}$	0.040*** (0.0137)	0.0356*** (0.0129)
$PROF_{i(t-1)}$	– 0.011 (0.0078)	– 0.0121 (0.0077)
Nr. Obs.	9769	9556
Log likelihood	– 2121.35	– 2063.27
Pseudo R^2	0.04	0.04

Note: marginal changes, standard errors in parentheses; ***/**/* denote resp. significance at 1%/5%/10%.

References

Allison P. D. and J. Scott Long (1987), "Interuniversity Mobility of Academic Scientists", *American Sociological Review*, 52, pp, 643-652.

Allison P. D. and J. Scott Long (1990), "Departmental Effects on Scientific Productivity", *American Sociological Review*, 55, pp. 469-478.

Ault D. E., G. L. Rutman and Th. Stevenson (1979), "Mobility in the Labor Market for Academic Economists", *American Economic Review (Papers and Proceedings)*, 69, pp. 148-153.

Ault D. E., G. L. Rutman and Th. Stevenson (1982), "Some Factors Affecting Mobility in the Labor Market for Economists", *Economic Inquiry*, 20, pp. 104-132.

Baker G., M. Gibbs and B. Holmstrom (1994a), "The Internal Economics of the Firm: Evidence from Personnel Data", *Quarterly Journal of Economics*, 109, pp. 881-919.

Baker G., M. Gibbs and B. Holmstrom (1994b), "The Wage Policy of a Firm", *Quarterly Journal of Economics*, 109, pp. 921-955.

Baker G., M. Gibbs and B. Holmstrom (1995), "Internal Labor Markets: Too Many Theories, Too Few Facts", *American Economic Review (Papers and Proceedings)*, 85, pp. 255-259.

Becker G. (1962) "Investment in Human Capital: A Theoretical Analysis", *Journal of Political Economy,* 70, pp. 9-49.

Ben-Porath Y. (1967), "The Production of Human Capital and the Life Cycle of Earnings", *Journal of Political Economy*, 75, pp. 352-365.

Bernhardt D. (1995), "Strategic Promotion and Compensation", *Review of Economic Studies,* 62, pp. 315-339.

Bhargava A., L. Franzini and W. Narendranathan, (1982), "Serial correlation and the fixed effects model", *Review of Economic Studies*, 49, pp. 533-549.

Carmichael H. L. (1988), "Incentives in Academics: Why Is There Tenure?", *Journal of Political Economy,* 96, pp. 453-472.

Chevalier J. and G. Ellison (1999), "Career Concerns of Mutual Fund Managers", *Quarterly Journal of Economics*, 114, pp. 389-432.

Colander D. (1989), "Research on the Economics Profession", *Journal of Economic Perspectives*, 3, pp. 137-48.

Coupé T. (2000), "Revealed Performances: Worldwide Rankings of Economists and Economic Departments", mimeo, ECARES.

Coupé T., V. Smeets and F. Warzynski (2004), "The Wage Policy of U.S. Economics Departments", mimeo, Aarhus School of Business.

Doeringer P. and M. Piore (1971), *Internal Labor Markets and Manpower Analysis*, Lexington, MA, D. C. Heath.

Dohmen T. J., B. Kriechel and G. A. Pfann (2004), "Monkey bars and ladders: The importance of lateral and vertical job mobility in internal labor market careers", *Journal of Population Economics,* 17, pp. 193-228.

Fama E. (1980), "Agency Problems and the Theory of the Firm", *Journal of Political Economy,* 88, pp. 288-307.

Ghosh S. and M. Waldman (2004), "Standard Promotion Practices versus Up-or-Out Contracts", mimeo, Cornell University.

Gibbons R. and L. Katz (1992), "Does Unmeasured Ability Explain Inter-Industry Wage Differentials", *Review of Economic Studies*, 59, pp. 515-535.

Gibbons R. and K. J. Murphy (1992), "Optimal Incentive Contracts in the Presence of Career Concerns: Theory and Evidence", *Journal of Political Economy*, 100, pp. 468-505.

Gibbons R. and M. Waldman (1999a), "A Theory of Wage and Promotion Dynamics Inside Firms", *Quarterly Journal of Economics*, 114, pp. 1321-1358.

Gibbons R. and M. Waldman (1999b), "Careers in Organizations: Theory and Evidence" In: O. Ashenfelter and D. Card (Eds.), *Handbook of Labor Economics*, Vol. IIIB, North Holland.

Gibbs M. and W. Hendriks (2004), "Do Formal Salary Systems Really Matter", *Industrial and Labor Relations Review,* 58, pp. 71-93.

Graves P. E., J. R. Marchand and R. Thompson (1982), "Economics Departmental Rankings: Research Incentives, Constraints and Efficiency", *American Economic Review*, 72, pp. 1131-1141.

Hirsch B. T., R. Austin, J. Brooks and J. B. Moore (1984), "Economics Departmental Rankings: Comment", *American Economic Review,* 74, pp. 822-26.

Holmstrom B. (1982), "Managerial Incentive Problems: A Dynamic Perspective" In: *Essays in Economics and Management in Honor of Lars Wahlbeck,* Swedish School of Economy.

Hong H. and J. D. Kubik (2003), "Analyzing the Analysts: Career Concerns and Biased Earnings Forecasts", *Journal of Finance*, 63, pp. 313-351.

Hong H., J. D. Kubik and A. Solomon (2000), "Security Analysts' Career Concerns and Herding of Earnings Forecasts", *RAND Journal of Economics*, 31, pp. 121-144.

Jovanovic B. (1979), "Job Matching and the Theory of Turnover", *Journal of Political Economy*, 87, pp. 972-990.

Kahn C. and G. Huberman (1988), "Two-Sided Uncertainty and "Up-or-Out" Contracts", *Journal of Labor Economics*, 6, pp. 423-444.

Lazear E. P. (1992), "The Job as a Concept" In: W. Bruns (Ed.), *Performance Measurement, Evaluation and Incentives,* Harvard Business School, Cambridge, MA.

Lazear E. P. (2000), "Performance Pay and Productivity", *American Economic Review*, 90, pp. 1346-1361.

Lazear E. P. (2004), "The Peter Principle: A Theory of Decline", *Journal of Political Economy*, 112, S141-63.

Lazear E. P. and S. Rosen (1981), "Rank Order Tournaments as Optimal Labor Contracts", *Journal of Political Economy,* 89, pp. 841-864.

LIMA F. and P. T. PEREIRA (2003), "Careers and wages within large firms: evidence from a matched employer-employee dataset", *International Journal of Manpower*, 24, pp. 812-835.

LONG J. S. (1978), "Productivity and Academic Position in the Scientific Career", *American Sociological Review*, 43, pp. 889-908.

NIEMI A. W. Jr. (1975), "Journal Publication Performance during 1970-1974: The Relative Output of Southern Economic Departments", *Southern Economic Journal*, 41, pp. 97-106.

PRENTICE R. L. and L. A. GLOECKER, (1978), "Regression Analysis of Grouped Survival Data with Application to Breast Cancer Data", *Biometrics*, 34, pp. 57-67.

ROSEN S. (1986), "Prizes and Incentives in Elimination Tournaments", *American Economic Review*, 76, pp. 701-715.

SCHARFSTEIN D. S. and J. C. STEIN (1990), "Herd Behavior and Investment", *American Economic Review*, 80, pp. 465-479.

SCOTT L. C. and P. M. MITIAS (1996), "Trends in Rankings of Economics Departments in the US: An Update", *Economic Inquiry*, 34, pp. 378-400.

SIOW A. (1995a), "Specialization, Obsolescence and Asymmetric Information in Academia", working paper, University of Toronto.

SIOW A. (1995b), "The Organization of the Market for Professors", working paper, University of Toronto.

WALDMAN M. (1984), "Job assignments, signalling, and efficiency", *Rand Journal of Economics*, 15, pp. 255-267.

WALDMAN M. (1990), "Up-or-Out Contracts: A Signalling Prespective", *Journal of Labor Economics*, 8, pp. 230-250.

ZABOJNIK J. and D. BERNHARDT (2001), "Corporate Tournaments, Human Capital Acquisition, and the Firm Size-Wage Relation", *Review of Economic Studies*, 68, pp. 693-716.

Part IV

Student behavior

Clicks and bricks: Tuning the promises of information and communication technologies (ICT) with students' practices

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Summary

With the increased importance of information and communication technologies (ICT) in educational policies, it has become commonplace to consider that these tools enable fundamental transformation in all aspects of higher education. ICT are thus seen to offer key opportunities in terms of learning and teaching. Commonly presented as a rich and stimulating academic information resource, the Internet is assumed to be taken-for-granted in students' academic life. In this way students are considered to be inherently technology competent and information literate. Within this perspective, this paper presents the results of a survey (n = 453) and interviews (n = 69) addressing the following questions: (1) to what extent are students integrating ICT tools (and the Internet in particular) in their current academic activities? (2) what is the role and place of electronic-based information sources compared to other sources and channels of information-seeking? and (3) are students' information-seeking behaviors patterned by disciplines and year of study?

1. Introduction

It has almost become a truism to assume that information and communication technologies (ICT) are at the root of deep and fundamental transformations in all aspects of higher education. They are heralded by many as *the* solution to drive the reconstruction of the university sector in the so-called 'knowledge society', especially in a context of fierce competition among education institutions: "(…) the main question these days does not seem to be whether they [colleges and universities] should adopt ICT in their study programs, nor the many consequences this might have for higher education, but rather how fast they can realise in practice the opportunities the new technology is offering" (Stensaker and *al*., 2007, p. 418).

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ICT are thus seen as a technological imperative offering the promises of key opportunities in terms of learning and teaching as well as in terms of literacy in affecting profoundly the way teachers, researchers and students gain access to information. Visions of 'virtual classrooms', 'virtual libraries', 'wired universities', 'cyber-campus' or 'e-universities' have therefore proliferated in the education literature.

Commonly presented as a rich, diverse and stimulating academic information resource, the Internet in particular is assumed to be taken-for-granted in students' academic life, progressively displacing all 'older' information resources. In this way, students, supposedly to be the digital generation – a generation "born with the chip" for whom computers and the Internet are "part of their cultural DNA" (Abram and Luther, 2004) – are claimed to be inherently technology competent and information literate.

This optimistic rhetoric has urged governments and higher education institutions to massively invest in ICT (Finkelstein *et al.*, 2000).

Contrary to the popularly-held view and somewhat sensationalist accounts often based on a strong faith in technological progress, a critical social science discourse has emerged around higher education and ICT. A wave of researches (Cuban, 1986, 2001; Dutton and Loader, 2002; Feenberg, 2004; Hara and Kling, 2002; Kling, 2000; Robins and Webster, 2002; Selwyn, 2002, 2003, 2007) critique the narrow angle of the dominant deterministic perspective of technology and higher education, which fails to address questions about how ICT currently work *in practice* when introduced into higher educational settings. To frame a more *realistic* discussion of technology in universities, these authors underline the need to move away from a predetermined linear model towards a multi-layered perspective which takes into account wider social, political, economic and cultural concerns (Selwyn, 2000).

Rooted into the social shaping of technology perspective (MacKenzie and Wajcman, 1996; Williams and Edge, 1996), this alternative approach underscores the set of options that technology offers to the university. However, those options are not unlimited but bounded within its social, institutional and historical contexts (Cuban, 1986; Pelletier, 2005).

In this vein, some researchers complain about the lack of extensive empirical studies that take a contextual student-centred perspective, arguing that educational computing literature fails to adequately consider the needs of those who are primarily concerned by the transformation of the university into a 'digital academe' (Dutton and Loader, 2002). Indeed, systematic empirical evidences about the extent to which students are taking up these much hyped Internet opportunities for literacy are still needed. It remains also unclear whether the use of the Web for information-seeking represents a significant change in students' academic life or, less dramatically, simply a new medium to achieve familiar ends (Slaouti, 2002).

It is thus pertinent to provide a more realistic account about the way ICT are incorporated into students' academic day-to-day activities as well as to explore the set of factors which mediates this (non) engagement with ICT during the university experience. Deconstructing this 'black box' (Bijker and Law, 1994) may then help to better understand what role can and, maybe more important, *cannot* play ICT in higher education.

The aim of this study is to address the issue through the analysis of students' attitudes towards digital information tools (the Web and the Internet in particular) that support their information-seeking behaviours for academic purposes.

2. Research questions

Before examining in more details students' information research activities, it is pertinent to better enlighten what kind of 'technology-literate generation' students are in general. Hence, a first research question is: *to what extent are students integrating ICT tools (and the Internet in particular) in their current academic activities?*

Regarding the main research concern of this study, the second research question is: *what is the role and the place of electronic-based information sources compared to other sources and channels of information-seeking?*

In order to gain a better understanding of information-seeking strategies, we enquired also the role of academic disciplines and of the year of study as potential 'moulding' factors of information-seeking strategies. Indeed, several studies have investigated the information needs and information-seeking behaviours of scientists and students in various disciplines, mostly in so called 'hard' sciences (Brown, 1999; Kling and McKim, 2000; Majid and Tee Tan, 2002; Talja and Maula, 2003; Whitmire, 2002) and it was of interest to extend this type of comparison to more 'soft' sciences students. The last dimension (seniority) is seldom explored, studies tending to be limited to graduate, undergraduate or first year incoming students (most of the time in one discipline).

Consequently, our last research question is: *are students' information-seeking behaviours patterned by disciplines and year of study?*

The underpinning interest of the present research is to understand how students choose and select sources of information in order to build a seeking strategy for academic purposes and to see whether there are contextual variables shaping and orienting their choices.

3. Research methods and instruments

Results of this research are based on data gathered during the academic year 2005 – 2006 at the *Université Libre de Bruxelles* through a multi-methods research design combining a quantitative instrument (questionnaire survey) and a qualitative tool (semi-structured interviews). Given our focus on contextualizing the use of ICT, this multi-methods approach enables a 'triangulation' of findings arising from the 'ground' in order to elicit various dimensions of students' approaches and behaviours.

While the first approach highlights main patterns of students' ICT use, the qualitative one captures the variety of the individualized experiences and contexts of these practices, complementing the 'what' and the 'when' of the survey details with more of the 'why' and 'how' (Selwyn, 2000; Selwyn, Gorard and Furlong, 2005, p. 41). Although this combination is widely valorised (Flick, 1998), it remains that such an approach is generally lacking in the literature. Here, the qualitative method performed a twofold role in supporting the questionnaire design as well as in interpreting the quantitative findings.

The first stage of the data collection involved exploratory face-to-face semi-structured interviews with 25 students from various disciplines. Results of the analysis of responses were used to point out elements to be integrated in the questionnaire.

In the second stage of data collection, a structured questionnaire was designed and administered. This tool was articulated into (1) a general information section (personal details and technological antecedents); (2) a computer and Internet section (access, frequency, kinds of usages, self-assessed proficiency and attitudes towards the Web, the Internet and PCs) and (3) a set of items dealing with the information-seeking behaviours of students for academic purposes (*via* the Internet in particular but without neglecting all sorts of paper-based information-seeking practices as well as more 'personal' channels such as advices from mates, instructors or any other 'human' source).

The last tier of data collection involved in-depth semi-structured interviews with 69 students. Respondents came from different disciplines and spanned the full range of study year groups. The interviews covered a range of open-ended questions related to students' perceptions and use of ICT in their academic and non academic daily lives. A number of more specific questions were also asked related to students' information research strategies and the role of the Internet as an academic information resource. In this way, interviews approached a 'life-story' method which enabled a deeper understanding of how ICT use (or non-use) fitted into students' wider information research practices and life habits.

This dual methodological approach gave us the possibility to enlighten the same research questions using different kinds of data and lenses. In this perspective, we mobilised the qualitative material to better interpret and sometimes corroborate the quantitative one.

Presentation of the findings takes into account the complementarities of the two approaches. Quantitative results are completed with interviews excerpts that try to better enlighten, with more nuanced information, the overall picture of students information-seeking strategies.

4. Participants

Participants in this study were students enrolled at the Université Libre de Bruxelles. Students received the questionnaire during classes and, in some cases, have been asked to fill it in before the class, or asked to bring it back filled in the following session. The support and coordination of teachers resulted to be determinant. All responses were anonymous and participation was voluntary.

In total, 453 usable questionnaires were collected. The range of the respondents' ages was 18 to 47 years, with a mean age of 20.6 (SD = 2.33). There were 42.2 % male respondents (n = 191) and 57.2 % (n = 259) female respondents (3 did not provide their gender).

Six disciplines were involved: Psychology (24.8 %, n = 112), Applied sciences (23.5 %, n = 106), Sciences (22.6 %, n = 102), Social and political sciences (11.9 %, n = 54), Humanities (9.5 %, n = 43) and Pharmacy (7.7 %, n = 35). In terms of the hard/soft division, hard sciences students (i.e. Applied sciences, Sciences, and Pharmacy) represented 53.8 % (n = 243) of the sample and was populated mainly by men (61.4 %, n = 148). The soft sciences group (i.e. Psychology, Social and Political Sciences, and Humanities) represented 46.2 % of the sample (n = 209) and exhibited an opposite gender connotation: there were 79.3 % (n = 165) female students.

Data from the qualitative semi-structured interviews came from sixty-nine students (44 in soft sciences and 25 in hard sciences). Interviews lasted on average between one hour and one hour and a half. Questions dealt mainly with their use of the Internet in general as well as their research strategies for academic work. All the interviews were recorded with the respondents' consent and transcribed.

5. Results

A. General computers and Internet usage: some quantitative indicators

1. Experience with computers

69.4 % of students owned a computer while 30.6 % had access to a computer owned by somebody else (usually a parent, a brother, a sister or a mate). Overall, their level of satisfaction with access to a computer was relatively high since 78.7 % of them declared to be 'satisfied' or 'totally satisfied' with their access to a computer and 21.3 % were neutral ('nor satisfied, nor dissatisfied'). Nevertheless, 12.2 % were less satisfied due to the fact that they had to share a PC with other persons.

Students' experience with computers ranged from less than one year to more than 15 years (Table 1).

Table 1 Computer use seniority

< 1 year	*Between 1 and 2 years*	*Between 3 and 4 years*	*> 4 years*
2.7	3.6	19.8	74.0

Note: Percentage of respondents (n = 453).

The average time of reported computer experience was close to 7 years (M = 6.9, SD = 3.6). There was a statistically significant difference between female (M = 5.88, SD = 3.86) and male students (M = 8.18, SD = 3.86 – [t (330.77) = 6.85, p < 001]). Hard sciences students (M = 7.83, SD = 3.66) had also a significant longer experience compared to soft sciences students (M = 5.74, SD = 3.14 – [t (447) = 6.43, p < 001]).

Students in this sample were not 'heavy' users of computers in terms of time spent in front of a screen (Table 2). On average 67.5 % reported to use a computer less than an hour per day (15.6 % reporting no use at all) but 16.7 % reported that they used a computer more than two hours a day (9.1 % between two and three hours and 7.6 % more than three hours).

Table 2 Average time spent with computers

< 1 hour/day	*Between 1 and 2 hours/day*	*> 2 hours/day*
67.5	15.8	16.7

Note: Percentage of respondents (n = 453).

If not time intensive users, students appeared to be frequent users since 44.5 % used it everyday and 34.9 % at least on a weekly base (Table 3).

Table 3 Frequency of computer use for all purposes

Never / From time to time	*1 to 2 times a week*	*3 to 4 times a week*	*Everyday*
20.6	19.0	15.9	44.5

Note: Percentage of respondents (n = 453).

For amount of work time on the computer ('*What percentage of your time sitting in front of a PC do you devote to your academic work?*'), 34.7 % indicated less than 50 % and 19 % said they devoted more than 75 % of their time using a computer for their academic work (Table 4).

Table 4 Proportion of time spent in front of a computer for academic purposes

< 50 %	*Between 50 and 75 %*	*> 75 %*
34.7	46.2	19.0

Note: Percentage of respondents (n = 453).

Students mainly used the computer at home (Table 5). 84.3 % declared using a PC at home 'regularly' or 'often' and rather 'seldom' at the university. Table 5 shows the answers in terms of place of access.

Table 5 Computer use access

Where do you use a computer and how often?			
	Never/Sometimes	*Often*	*Regularly*
Home	15.8	16.3	67.9
Campus library	92.0	5.6	2.4
Campus laboratories	80.0	14.0	6.0

Note: Percentage of respondents (n = 453).

2. *Experience with the Internet*

With regard to the Internet, it appeared that the Internet was fully integrated into students' daily activities (Table 6). A large majority of them (86.2 %) stated that they have been using the Internet for more than three years.

Table 6 Internet seniority

< 1 year	*Between 1 and 2 years*	*Between 3 and 4 years*	*> 4 years*
2.4	11.4	35.9	50.3

Note: Percentage of respondents (n = 453).

Students' self-reported use of the Internet for all purposes revealed that the Web is an important tool: 51.9 % reported using the Internet 'everyday' and 17.3 % at least several times a week (Table 7).

Table 7 Frequency of use of the Internet for all purposes

Never / From time to time	*1 to 2 times a week*	*3 to 4 times a week*	*Everyday*
13.2	17.5	17.3	51.9

Note: Percentage of respondents (n = 453).

Nevertheless, this regular use was relatively moderate since a majority of students (59.8 %) stated spending less than one hour per day on the Internet. Although, nearly two students out of ten (19.8 %) declared spending more than two hours per day with this tool (Table 8).

Table 8 Average time spent on the Internet/day

< 1 hour/day	*Between 1 and 2 hours/day*	*> 2 hours/day*
59.8	20.4	19.8

Note: Percentage of respondents (n = 453).

Regarding Web usage for academic purpose, only, 17.3 % declared to dedicate more than 75 % of their Web usage for these purposes. A majority of them (53 %) indicated therefore using the Web less for university than for non-academic activities (Table 9).

Table 9 Proportion of time spent on the Internet for academic purposes

< 50 %	*Between 50 and 75 %*	*> 75 %*
53.5	29.1	17.3

Note: Percentage of respondents (n = 453).

These statistical results constitute a first indicator of the place of the Internet in the day-to-day students' lives. Students performed a more or less daily usage of Internet. Moreover, this usage was often of non academic nature, thus university did not emerge as the *locus deputati* for Internet use.

B. Internet usage: a view from the trenches

Taking advantage of the multi-method approach, we pushed further the analysis of the quantitative data with the words of the users' side of the fence. Interviews confirmed this major trend: though students have fully integrated ICT in their life, the majority of them did not show any fanatical or obsessive relation towards this tool. Nevertheless, it was clear from our interviews that ICT – and the Internet in particular – play an integral part in the day-to-day lives of most responding students, as this student said:

> "Today, the Internet is an essential tool in student's life. It's a tool you must be able to use. We must live with our time (…). Without the Internet, I do not know how I would do my work at the university. For instance, you get a lot of summaries of lectures and all types of academic information you need from the Internet. For a student like me (…), the Internet saves an incredible amount of time" [2] (Applied sciences student, third year).

Another student expressed the view that:

> "(…) I use it [the Internet] every day… It's more practical, it's faster, and you can do tons of things. In fact, now, I search everything on the net. For my work also I search on the Internet, I have a tendency to say 'why search elsewhere if all the information is there'" (Psychology student, third year).

However, at the same time, it appeared also that the Internet was not perceived as a value in itself. This tool had, first of all, an instrumental value according with this student in Geography:

> "Of course Internet is always within my reach when I need it, I regularly connect to Internet during the day, but I do not spend ages surfing. I use it when I am looking for precise and specific information. In this way Internet is a highly useful tool" (Geography student, third year).

In the same vein:

> "If I find some interest in Internet it is not because I am addicted or particularly keen on the technology, but simply because this tool can be helpful. Today, it is true, we are asked to work rapidly (to deliver homework), and then the only way to survive is to go on Internet" (Social sciences student, second year).

Therefore, although recognizing the central role of the Internet in their activities, other students took a fairly detached, critical view of the role of this tool in their day-to-day academic research activities:

> "Internet is an indispensable component in my academic as well as non-academic life but I don't manage all my life via my computer". Question: what do you mean? "I mean that ITs do not change my way of thinking. It's just a question of tools. When I am seeking information, I still like to be in the academic library, to write down the reference and going directly to take the books I need. I still like books and enjoy the paper sheet feeling. You would see how many books I have in my bedroom!" (Social sciences student, second year).

Far from an uncritical assessment of the Internet as a revolutionary academic tool, some students – though frequent users of the Internet – discussed its academic 'usefulness' in mixed and limited terms: the 'absolute usefulness' of the Web was felt to jar with the prevailing rhetoric of educational usefulness which the students were generally exposed to, as this student explained:

> "I never find relevant information for my university papers. I always hear everywhere that the Internet is the new leading edge media for information research but,

[2] Interviews were conducted in French. Translations are ours.

personally, around me, among my friends, none focus his/her academic information research on the Internet, because they seldom find something interesting for their research topic. Me too, for my final study paper for example, I don't try to seek a lot on the Internet! I find the Internet very useful to communicate and chat with my friends but not as an academic information resource" (Humanities student, fourth year).

As a whole these results relative to the place of Internet in the students' everyday life showed that the communication and information technologies, even though ingrained in the day-to-day for the majority of the sample, did not create any behaviours leading to an oversized investment in terms of time and overwhelming passion in terms of academic use.

Far from spending their entire day with the keyboard at their fingertips, we can hardly label these students as "*mutants*" (Lardelier, 2006, p. 13) or as "hyper-connected". The reduced amount of time they devoted facing a screen invalidated the stereotype commonly conveyed of the youngster plugged 24 h/ 24 h to these tools and totally dependent to them. On the contrary, the picture showed a regular user but at the same time moderate and reasonable. Even when the ICT use became more constant students did not seem to perform compulsive behaviours getting lost in the maze of the cyberspace. Far beyond an end in itself Internet was for a good part of our sample a rapid and effective mean helpful to reach their goals.

Within this approach students established a functional and instrumental relation with these technologies. At this stage, no element brought over a 'cyber-mania contamination' prodigy.

C. *Role and place of the Web: an important trigger of the research process*

1. *Quantitative measures*

With regard to the second research question, results revealed that students used the Internet for information-seeking activities related to academic activities: 49.6 % declared to use it at least once a week (6.7 % reported 'rarely' or 'never') for assignments or essays and 43.3 % mobilised it with the same frequency to collect lecture notes (Table 10).

Table 10 Frequency of Web's uses for academic purposes

Usage type	*Never/ Rarely*[a]	*At least once a month*	*At least once a week*	*Mean*[b]
Communicate with other students	20.1	27.2	32.7	2.73
Seek information for assignments and reports	6.7	43.8	49.6	2.66
Collect lecture notes	15.9	40.8	43.3	2.43
Consult students' forums	43.5	19.7	36.8	2.20
Communicate with lectures or teaching assistants	61.1	30.8	8.0	1.52

Note: [a] Percentage of respondents (n = 453); [b] Mean based on a scale with: 1 = 'Never/Rarely' to 5 = 'Nearly everyday'.

When students have been asked ‘what’s for they are using the Web during the information seeking process’, results show (Table 11) that the role of the Internet in students’ information-seeking strategies was shared between two main goals: being a guide for a synoptic view of a new subject for which they had to provide an essay or report (74.3 % declared that they used the Internet regularly for that purpose) and being a complementary source of information (74.2 %, on a regular base). These aims were more frequent than searches for more in-depth information but, still, 50.9 % mobilize the Web for that purpose.

Table 11 Web’s role and frequency

Use the Internet for…	*Never*	*Sometimes*	*Often*	*Regularly*	*Mean*[a]
Overall view of the subject	8.5	17.2	32.1	74.3	3.08
In-depth information	17.9	31.3	29.2	50.8	2.55
Complementary information	6	19.9	44.1	74.1	2.98

Note: percentage of respondents (n = 447); [a]Scale: 1 = Never to 4 = Regularly.

From an overall perspective thus, students used Internet as a source of information when they needed an overall glance on the subject. This source is equally exploited by a vast majority when they look for complementary information. The Web’s role was less popular when more elaborated and deep information was needed.

Table 12 Students’ use of various information sources for schoolwork

Information-seeking research items	*Mean*
Surfing on the Web	4.11
Other students/mates help	3.22
Online library catalogue (books)	3.18
Tracking strategies	2.83
General press	2.70
Online catalogue for scientific journals	2.70
Library personnel support	2.64
Assistants/lecturers’ help	2.64
Browsing the library hallways	2.39
Other universities’ online catalogues	2.06
Online catalogue – end of year works	2.33
Bibliographic databases	2.15
Official institutional databases	1.83
Table of contents of electronic journals	1.82

Note: Scale: 1 = ‘do not know’ to 5 = ‘I always use’; n = 448.

In order to push the investigation further, we also tried to shed light on the place of the Web in searching strategies compared to other information resources. The questionnaire asked students to rank 14 possible sources of information they used *when starting a new essay* on a 5 point scale (1 = 'Do not know' to 5 = 'I always use').

Results (Table 12) demonstrate that search engines played a 'leading' role (M = 4.11), followed by searching the online library catalogue for books (mean = 3.18) and asking help from colleagues (M = 3.22). None of the other items emerged as being systematically used. It seems though that students, in general, diversified their strategies and tools, adding as well the informal reachable side of the information-seeking issue (asking assistance from other colleagues). At the same time they tended to ignore some other tools such as scientific journals, online catalogues and official databases.

2. Qualitative testimonies

Taking the opportunity to broaden the question of the role and the place of the Web through qualitative interviews, researchers asked students to explicit their information searching strategy. Qualitative data underlined similar trends than the quantitative one. Indeed, for a large majority of students, the Internet appeared to be an entry-point or trigger in the information-seeking process, rapidly playing a complementary role, as was typically underlined by a student in Applied sciences:

> "My tactic when searching for information is to first surf on the Web and, from there, I go to the university library and, above all, to specialized libraries at our department" (Applied sciences student, third year).

Another explained that:

> "I use Google to start my research. I sort out what I get, I keep some links. Often, it is to get into the swing of things. From there… I use the information as a base… In general the Internet helps me to structure my work" (Communication studies student, third year).

Adopting a very pragmatic information research strategy, a student studying Social sciences expressed the advantage in term of gain of time when seeking information for the university:

> "You do not necessary need to make a big amount of information research for academic purposes. For the little homework I have already made, I have been first surfing on Internet, and this is a terrific clearing out step, starting from that, I drop on authors, books, citations that bring you to other sources. In this case or I go checking if the book is available at the university, or I order it" (Social sciences student, fourth year).

In the same vein, time-cost benefit of the Internet for this purpose was also underlined by this student who had just begun studying History. Nevertheless far from being the only information-medium being used, Internet was always used in parallel with other resources of information. Here, the choice of not limiting her search to the Web was leaded by pragmatic concerns in order to fit the professor's requirements:

> "When I make a research for my homework, I always start from Internet. It is more rapid, more at hand but then I go on the search engine of the library, since I know that if the teacher gave us this work is to make us practice to find books at the library" (History student, first year).

For most students, then, the Internet played a complementary role in their academic information seeking and retrieval methods. Students therefore talked of the Internet's role in providing background or preparatory general information – and considered the Internet as being a part – rather than the total sum – of their overall research strategy:

> "When I am seeking information for academic papers, I use both print-based and Web-based information. I generally use the Web at the beginning of my research, when I seek to get a general idea of a topic. After that, I prefer going to the library. I don't know why but I have the impression I will find more precise information there" (Communication studies student, third year).

> "Internet is absolutely the first source I question for information but I would definitely lead parallel research at the library" (History student, first year).

As well as to be a good guide for a synoptic view of a new subject of research, the Internet provided also often complementary punctual source of information for courses or reports:

> "I use the Internet when I need to get a definition or something else precise that I don't understand in my textbook. For such type of research, Internet is very helpful. I'm at home in my sofa, I've just to click on the mouse and I get what I want. However, except for punctual information like this, I never use the Internet for academic assignments. I never write a paper with information found on the Web. I focus my information research on books or other kind of print-based information. Internet is a complement" (Humanities student, fourth year).

A similar view was echoed by a student in Applied sciences:

> "When a large amount of information research is concerned I always pass by the search engine of the library; I do Web surfing when I need precise and specific information. For instance when a course is badly given or when I miss information" (Applied sciences student, fifth year).

Another student in psychology stressed the merit of the Web as an encyclopaedic information-medium but nothing more:

> "Internet is just for precise and detailed information as when I studied the "instrumental troubles", for instance. It is not funny to read an entire book on that, I surf on Internet and in few moments I have a glimpse of the matter. I do not need to rummage the files. At this level Internet is really useful" (Psychology students, third year).

In this vein some students limited their searches on the Web to well-defined problems when this medium appeared to be the solely information resource which fitted with their information needs:

"Internet, I use it when there are names of authors I don't know. Contemporary authors for instance it's difficult to find about them in books" (Philosophy student, second year).

"(…) I think that the Web is not really essential for my studies. Moreover… I always start with the library (…) but when you need it, you need it, I use the Web when it's really inevitable, when I can't get the information elsewhere" (Mathematics student, second year).

In line with the pragmatic and the utilitarian nature of students' attitudes already suggested above, other students attempted to compromise between on- and off-line resources adopting selection criteria that witness how they assessed and perceived the information they found on the net as well as the supervising yet censored role of the teacher or lecturers:

"When I wrote my academic paper last year, I gathered some online articles on Google and Yahoo but I finally based my work on the information found in the library. I took some ideas from online articles but I didn't dare to cite the references in my paper. I realized that I cannot cite them because I didn't know where they come from" (Psychology student, second year).

The rationale behind this lack of 'scientific' authority of the Internet resources compared to the academic library ones is that library use – rather than the Internet use – is considered as the information seeking practice more commonly role-modelled by their professors.

Faced with their professors' tacit lack of attached importance to online resources, students described adopting varying pragmatic strategies in their academic coursework. Therefore, this student expressed how online-resources did not appear as an essential component of his information research practices to succeed in a course or to gain favour from his professors:

"Actually, I have to confess it, at the beginning I use Internet to get information on the subject but as I know it is not good to take documentation on Internet I then go to the library. Let's say I find easier to find info on the Internet. But I know that it is no fair and that we are not allowed" (Psychology student, fourth year).

Q: what do you mean?

"Teachers always tell us that we have to mistrust Internet, because it is not reliable as information resource and that they would prefer not to see Internet links address on the bibliography of our works".

Considering online sources as not a part of their professors' practices, students reasoned that it should not be part of their practice either. The Internet was thus felt to be a part of the 'hidden' university curriculum, as this student explained:

"I don't cite Internet references in my papers but often [laugh]… I take articles from the Web and I try to find the equivalent print-based reference to cite it in my paper. I know that professors prefer print-based references because Internet references are something temporary, it's too much virtual" (Communication studies student, fourth year).

All this quotations suggest that students' strategies were often guided by pragmatic and utilitarian concerns linked to the short-term or longer-term cost-benefit balance of efforts and achievements. They behaved in conformity with down to the earth rules: achieve homework within time and within an overall system of rules and consolidated practices (teachers' expectations and procedures). Yet pragmatic or not, all of these underlying rationales show us a limited and heterogeneous level of student's engagement with the Internet for academic research activities. All in all, survey data and interviews tended thus to point to a 'realistic' students' point of view: as useful and structuring as it is, the Internet has not supplanted other information resources but rather complemented them.

D. Crafting the information-seeking strategy: disciplinary differences?

1. Quantitative measures

Our second research question sought to better enlighten the role of two potential crafting factors in the shaping of the information research process: disciplinary differences and year of enrolment.

Statistical results regarding the hard and soft sciences contraposition give an insight in the understanding of the extent of the disciplinary effect on leading studying activities such as looking for information for coursework in terms of preference and variety of sources.

As far as frequency of use is concerned, it can be seen from Table 13 that students in human and social sciences were less frequent users than hard sciences students [χ^2 (2, 450) = 39.37, p < .001].

Table 13 Frequency of use of the Internet by discipline

	Hard sciences	*Soft sciences*
Never/From time to time	6.2	21.6
1 to 2 times a week	12.4	23.6
3 to 4 times a week/ Everyday	81.4	54.8

Note: Percentage of respondents within each set of disciplines (Hard sciences, n = 242; Soft sciences, n = 208).

Students from hard sciences exhibited also a different behavior compared to their counterparts in terms of time spent on the Internet (Table 14): the latter said that they used it less than the former [$\chi 2$ (2, 450) = 12.38, p < .005].

Table 14 Average time spent on the Internet by discipline

	Hard sciences	*Soft sciences*
< 1 hour/day	52.3	68.4
Between 1 and 2 hours/day	24.9	15.3
> 2 hours/day	22.8	16.3

Note: Percentage of respondents within each set of disciplines (Hard sciences, n = 242; Soft sciences, n = 208).

Table 15 shows that students in soft sciences focused more often their attention to a wider bunch of sources when searching for information: Internet search engines were in short list with the library electronic research tool for books. Other students' help was as well taken into consideration and online library catalogue for scientific journals together with general press sources or bibliographic databases. Conversely, hard sciences students used significantly more Internet search engines and turned more often to assistants/lecturers for guidance.

Table 15 Students' use of various information sources for schoolwork (Means for sample and hard/soft dichotomy)

Information-seeking research items	*Sample**	*Hard*	*Soft*	t^a
Surfing on the Web	4.11	4.25	3.93	3.51**
Other students/mates help	3.22	3.33	3.09	ns
Online library catalogue (books)	3.18	2.75	3.69	– 7.21**
Tracking strategies	2.83	2.82	2.84	ns
General press	2.70	2.56	2.86	– 3.05**
Online catalogue for scientific journals	2.70	2.56	2.91	– 2.98**
Library personnel support	2.64	2.19	2.04	ns
Assistants/lecturers' help	2.64	2.86	2.38	5.06**
Browsing the library hallways	2.39	2.32	2.48	ns
Other universities' online catalogues	2.06	1.97	2.17	ns
Online catalogue – end of year works	2.33	2.26	2.41	ns
Bibliographic databases	2.15	1.89	2.48	– 5.14**
Official institutional databases	1.83	1.69	1.99	– 3.06**
Table of contents of electronic journals	1.82	1.78	1.88	ns

Note: Scale: 1 = 'do not know' to 5 = 'I always use'; *Mean – total sample; t^a value *t*-test; **=p < .001; ns = not significant; Hard sciences, n = 242; Soft sciences, n = 208.

A section of the questionnaire was devoted to assess preferences of students for searching via the library or on the Web. Two scales were designed for this purpose. A first scale consisted of six items measuring preference for the Web (sample items: 'I prefer to search for information at the library instead of the Web' – reversed for calculating scale data; 'Since I use the Web, I spend less time consulting print-based documents at the library'). A second scale was intended to measure preference for the library as an information resource (sample items: 'Information I find at the library are more pertinent than the one I find on the Web'; 'At the library I generally find more accurate information than on the Web'). Internal consistency tests resulted in coefficient alphas equal to 0.87 for the first scale and 0.84 for the second scale.

Table 16 shows that students tended to prefer the library as an information resource. This is in line with findings of Divleko and Gottlieb (2002), who found that while undergraduates begin searching information using online sources, books and print journals are crucial components of submitted work. However, a deeper look at empirical results reveals that hard and soft sciences students differed significantly in their behaviours: whereas the first prefer searching on the Web, the latter prefer to use the library. It is also noteworthy that hard sciences students expressed the view that the use of the Web enhances the quality of their work more often than soft sciences students (see Table 17).

Table 16 Students' preferences for library search vs. Web search

Scale	*Sample mean*	*Hard sciences students*	*Soft sciences students*	*t*
Preference for the Web	2.92	3.15	2.64	6.08*
Preference for the library	3.43	3.25	3.64	-5.29*

Note: scale: *p < .001, n = 438.

Table 17 Does searching the Internet enhance the quality of your work?

	Disagree/ Totally disagree	*+/-*	*Agree/ Totally agree*	*Mean**
Soft sciences	28.6 %	50.5 %	20.9 %	3.19
Hard sciences	17.5 %	50.4 %	32.1 %	2.86

Note: *Difference significant at p < .001 (*t* = 3.97). Scale: 1 = 'Totally agree' to 5 = 'Totally disagree'.

These emerging trends show how student's choice and strategies when seeking for information for academic purposes are nuanced and diverse according what can be considered as a moulding factor in terms of learning scheme and practices: the study discipline (Lahire, 1997, 1998; Millet, 2003).

2. *Qualitative results*

Confirming similar trends, interviews helped moreover to better understand the various reasons underlying this difference between the both students' tribes in terms of information seeking strategies. As shown in the following excerpt, students in hard sciences disciplines tended to concentrate relatively more often their approach on Internet search engines:

> "Google, it helps really a lot… I don't know how I should do without Internet. Personally, in my view, I make the association research=Internet" (Applied sciences student, fourth year).

This was also the case of this student in Physics:

> "In general, when I make researches for academic purposes, I go on Internet, I take the info I consider interesting and I immediately put it in my favourite folder. It is easier for me. When you use it [the information] you re-tape it immediately, by cut and paste and you work with it" (Physics student, third year).

One of the reasons of the predominance of the Web in information seeking practices of hard sciences students is that the nature of online information resources simply fits with their courses' information needs:

> "In computer sciences you find everything on sites. It is not like in human sciences, you don't need to put references… What lecturers ask us is not to collect literature but to solve very precise problems" (Informatics student, fourth year).

Alongside traditional Web search engines, the use of more informal discussion platforms is also a frequent way to gather academic information resources for students in hard sciences:

> "To search information, I essentially use Google or Yahoo. Otherwise, I use forums. I ask questions and I wait for replies. Sometimes it works really well. It is the part of Internet that occupies most of my work" (Applied sciences student, third year).

Compared to soft science students, they also tended to request more often assistance for information-seeking from teaching staff or colleagues. This pattern was expressed by this student:

> "For the work I had to do last year, I searched with Google. My tactic was to find a sample of pages and to click on the first link. If it doesn't suit me, I go to the second and so on. But I don't go to the library, it is not a reflex I have. Even before I had an access to Internet, it was not a reflex to go to the library. Or I have the book at home, or I ask my lecturers or people around me" (Biology student, third year).

Another student in Geography explained that professors' assistance is sometimes a quickly and less time-consuming option than conventional methods:

> "To make researches, roughly speaking, I go to the library, but I ask help as well to the teachers. I do not want to bother too much" (Geography student, third year).

For some of them, even, such informal research strategies appeared to be the best alternative to gather academic information:

> "If I remember well, I think we followed a training in information and documentary research methodology, during the first two year; but I would say it was of little use according to me, a good research tool to find a book is to ask to the teaching assistants. We need to keep it in mind; it is one of the best, if not the best mean to find information on a subject matter" (Applied sciences student, fifth year).

In contrast, many students in soft sciences professed a clear preference for the academic library over the Internet for accessing articles and books for their university assignments. The following excerpt was emblematic of the attitude of many soft sciences students:

> "I start immediately with the library and take a lot of books… I then go to the computer, I type a keyword large enough and then I go to the shelves. I even do not go on the Internet" (Political sciences student, second year).

One recurring theme of this preference throughout students' interviews is the perceived 'scientific' legitimacy and authority of the academic library resources in their studies discipline. For a majority of them then, the library was still seen as the cornerstone of 'serious' and valuable academic research activity:

> "When I will complete my final study paper, I think I will mobilize print-based information from the library rather than Web-based resources because I do not even think I will find something 'scientific' for my topic on the net. Moreover, most of our professors dissuade students from using them. We have no evidence that they have a 'scientific value'" (Humanities student, fourth year).

As this student in Psychology also described, the idea of 'scientific' value of the academic library is reinforced by the fact that library resources are perceived to be considered as the 'legitimate' knowledge by their professors:

> "Using books or other kind of print-based information is more scientific between brackets. We know where the resources come from (…). They come from the academic library. It's what we learn at the university. Professors often warn students against the Web-based resource" (Psychology student, third year).

Another exploratory reason of this limited use of Internet-resources compared to library-based information might be found in the limited goodness of 'fits' of the Internet with some subject disciplines, as it was stated by some of our interviewees:

> "(…) My topic doesn't suit with the Internet! My research covers the question of the masculine identity in the men's fashion. When you type the keyword « fashion » on Google, you find a lot of different kind of commercial stuff but nothing interesting for an academic research. Another great disadvantage of the Internet is that the research is limited to keywords. Walking around in the academic library, I found many interesting books which don't contain the keyword 'fashion' or 'clothes' but which were relevant for my research topic anyway. Via Internet, I would have never found them!" (Humanities student, fourth year).

The issue of how the Internet 'fits' with some subject disciplines can also be seen with one of our interviewees who had learned to use a host of overseas on-line search engines and databases during one university degree course. However, she had little reason to use them because her academic essay covered very local-rooted topic:

> "I still know how the online searching engines that we have learned to use during the course work. However, I think I will not use them for my final study paper. I am not going to loose my time searching information on foreign data bases when my topic is very much national-rooted. It doesn't make sense! Once, I tried to use such type of online search engines but I didn't find relevant information for my academic paper. I remember that I seek with different keywords and I didn't find anything interesting. I didn't go then into too much details because it made me nervous and I stopped!" (Humanities student, fourth year).

In this case, her Internet-reticence was moreover reinforced by a lack of search skills and confidence often identified as a barrier to students' effective use. In a parallel direction, one rationale behind the preference of simply going to the academic library than searching on the Web is the sometimes constraining nature of information seeking by keywords via ICT tools. Thereby, the less-focused and more serendipitous nature of the library-based research allowing easier finding unintentional information was highlighted:

> "For my work last year I didn't know how to find information and then I went to look on Google even if I knew there was a lot of foolish information there and then I went to the library to look at books I found on the online catalogue but I couldn't find anything because I typed keywords which did not give results. Then, what I did is that I looked in the 'sociology of family' section in the library and I looked at the books one by one. Finally I found what I looked for" (Social sciences student, second year).

Therefore, alongside situational relevance is the associated issue of situational convenience of using the Internet as an academic information resource. For some students in humanities who were not very used to have recourse to this search engines, the Internet was not felt to be a comfortable research tool. Having originally learned 'manual' information research methods, some students were therefore reluctant to use an additional method and were more willing to rely on their well-known familiar strategies:

> "(…) A book is handier than a screen. It is easier to have a book or an article in your hands if you want to work on it! It is the reason why, when I find something interesting for my topic I always print it out. Perhaps, I am still a little bit reactionary, I don't know…" (Humanities student, fourth year).

The recurring tendency of many humanities students to prefer familiar 'offline' sources than Internet-based resources was also obvious in the discourse of this student:

> "When I'm seeking information for academic papers, I never find the information on the Internet as synthetic as print-based information…A book you can easily turn the pages. If you want to have a look at the references, you go immediately to that chapter…When you have 25 books in front of you, you take books one by one, books refer to other books and so on… You can get a better general idea on the topic. It is not the case with the Internet… I am somebody who find easier to have written materials in books in front of her" (Communication studies student, fourth year).

All these quotations reveal that personal students' involvement with online resources for academic purposes is above all a question of the situational relevance and/or convenience according to the existing academic discipline habits. Often, students did not engage with the Internet as an academic information resource because it simply did not 'fit' with the pre-set discipline's academic research activities patterns as well as their personal ones. In some case then, the Internet was not considered by students as the easiest and most familiar way for searching academic information.

This contrasts with the common notion that using ICT is inherently motivational for *all* students and that the Internet is an inherently convenient means of facilitating academic information research. Therefore, from the above data, we might say that discipline matters in the orientation and in the 'construction' of information-seeking strategies. The sources' choices and preferences are varied and context-dependent.

E. Crafting the information-seeking strategy: seniority

1. Quantitative measures

Regarding to the second potential crafting factor in the shaping of the information research process – the year of study – first and second year students' preferences have been compared with third year (and above) students. It has been presumed that older students are in an academic path more demanding in terms of reports and papers. The underpinning research's motivation behind such comparison is to test whether the given situational moment in a student track might affect the way the student takes on a documentary research and the information resources he/she mobilizes.

Table 18 summarises the different sources ranked by means according with the year of enrolment. Results show that senior students pushed a little bit further their information research strategies than the younger ones. Indeed third year students (and above) had significantly more recourse to the Internet search engines and online library catalogues for scientific journals and books.

Table 18 Students' use of various information sources by seniority (Means for total sample and 1st-2nd/3rd year and +)

Information-seeking research items	*Sample*	*1st/2nd year*	*3rd year and +*	t^a
Surfing on the Web	4.11	3.99	4.34	– 3.34**
Online library catalogue (books)	3.18	2.92	3.59	– 4. 37**
Tracking strategies	2.83	2.66	3.04	– 3.23**
General press	2.70	2.82	2.59	2.06*
Online catalogue for scientific journals	2.70	2.41	3.14	– 5.26**
Library personnel support	2.13	2.19	2.06	ns
Other universities' online catalogue	2.06	1.97	2.32	– 2.98*
Online catalogue – end of year works	2.33	2.12	2.61	– 4.55**
Bibliographic databases	2.15	2.03	2.28	– 2.01*
Table of contents of electronic journals	1.82	1.54	2.08	– 5.29**

Note: Scale: 1 = 'do not know' to 5 = 'I always use'; t^a Value of t for the *t*-test; *$p < .05$; **$p < .001$.

They also mobilised tracking strategies and bibliographic databases or electronic journals more often than younger students. Compared to the latter, they tended then to diversify their information-seeking strategies. In contrast, younger students seemed to be mainly oriented towards two main sources: Internet research engines and networking with colleagues. They ignored journals or official databases and privileged general press versus other online tools (mainly online catalogues for books).

Looking at the hard/soft dichotomy for various items (Table 19), online catalogues for books and scientific journals were more used by older students than younger ones.

Table 19 Students' use of various information sources by discipline and by seniority

Information-seeking (selected) items	*1st/2nd year*			*3rd year and +*		
	Hard	*Soft*	*t*	*Hard*	*Soft*	*t*
Online library catalogue (books)	2.31	3.44	– 7.17***	3.28	4.42	– 5.42***
Online catalogue (scientific journals)	2.13	2.64	– 3.54***	3.01	3.66	– 2.97***
Surfing on the Web	4.02	3.95	ns	4.53	3.85	4.85***
Assistants/lecturers' help	2.69	3.39	2.65**	3.06	2.34	4.06***
Other students/mates help	3.38	3.12	2.24*	3.27	3.02	ns
Tracking strategies	2.69	2.64	ns	2.98	3.40	– 2.28***

Note: *= $p < .05$; **$p < .01$; ***$p < .001$.

It appeared also that asking help from lectures was more important to hard sciences students than to soft sciences students at both stages of the curriculum. Nevertheless, concerning the use of the Internet, one may notice that there is no significant difference between 'beginners' in both types of disciplines. The search engine played the 'leading' role compared to all other information resources possibilities. However, senior soft sciences students tended to use this electronic medium less than younger hard sciences students. Moreover, older students in the hard sciences used it more than younger students in the same field of study.

Returning to the role of the Internet in information-seeking strategies of students, Table 20 shows that older students used the Internet to gain an overall view of a new subject more often than younger students. There was, in contrast, no significant differences between these both students' tribes concerning the use of the Web in order to gather complementary punctual information as well as in depth ones.

Table 20 Web's role by seniority

Use the Internet for…	*1st/2nd year*	*3rd year +*	*t*
Overall view of the subject	2.94	3.37	– 4.25*
In-depth information	2.57	2.51	ns
Complementary information	2.94	3.06	ns

Note: Scale: 1 = 'Never/Rarely' to 4 = 'Regularly'; *$p < .0001$; ns = not significant.

Finally, looking for this concern at the hard/soft dichotomy again, it appeared from the results (Table 21) that older hard sciences students were more heavy users of the Internet than soft sciences students: the former used it more extensively than the latter in order to gather overall view of a subject, in-depth information as well as complementary punctual information.

Table 21 Web's role by discipline and by seniority

Use the Internet for…	*1st/2nd*			*3rd year +*		
	Hard	*Soft*	*t*	*Hard*	*Soft*	*t*
Overall view of the subject	3.07	2.83	2.05*	3.46	3.04	3.10**
In-depth information	2.61	2.53	ns	2.70	2.08	3.73***
Complementary information	2.96	2.92	ns	3.20	2.75	3.18***

Note: Scale: 1 = 'Never/Rarely' to 4 = 'Regularly'; *$p < .05$; **$p < .005$.

2. *Qualitative results*

In-depth interviews also highlighted the fact that senior students tended to perform more often than the younger ones a structured and articulated multi-sources strategy. Moreover they help to better enlighten some of the underlying rationale behind such pattern.

From our interviews, it was apparent that many young students did not have recourse to various kinds of information resources because they simply did not know how to use and manage them. As this student, who has just followed an information research methodology course explained:

> "Before this training I only questioned Google and the library search engine, I didn't even know that there are buildings hosting the publications (journals, periodicals) here at the ULB. Without this course**,** I was completely lost; I didn't know how to face my information seeking. I haven't a clue on what a database was. According to me a database, is Access for instance" (Social sciences student, second year).

A few interviews of students in their first years showed limited and random styles information seeking approaches, in which the Net occupied a dominant place as testified by this extract:

> "I do not exactly know how I find out information needed for my final work. I was on Internet and as I clicked on any links I drop on interesting information" (History student, first year).

Another student in Psychology took a similar view when she explained how she will take on her documentary research for an academic assignment:

> "For my final year work, I did not know how to sort it out, so I go and see on Google, even if I realise that there are some foolishnesses" (Psychology student, first year)**.**

As underlined by this student, it is due to a lack of knowledge of the available information seeking sources that the students felt back on the only channels and means they mastered and controlled: the generalist search engines. They questioned this source, despite the fact that they are aware of the limits and constraints in terms of quality and scientific reliability that the information taken from this source brings over.

Conversely senior students who had acquired experience in this cornerstone academic activity via documentary methodology courses and practices showed an increased info-seeking know-how:

> "At the beginning of my classes it was a real mess ! Actually I did not have any methodology; I think this is important to say. It was the total and complete blurry confusion, I search randomly, on Yahoo and Google but I found only phoneys. But after a training that I took during my second year I understood that I would have found the needed information on the literature documentary tools and database" (Philology student, second year).

A similar view was echoed by the following student who recognized all the benefits of extending their information-seeking behaviour:

> "During my first years, I only searched on the ULB library search engine and I looked randomly as for my work of midterm that really was my first big scientific work, with references, an argumentation etc. I did not have this reflex to go and look for key-word, make association, widen the research domain. I did not go further, with the practice and the experience I think to be less limited in the way I look for information" (Psychology student, fourth year).

Alongside the lack of students' training or experience in such activity another reason emerged as a barrier to a multiple data sources information seeking. The following narration showed that the mobilization of varied resources was perceived as needless and unfruitful when students were in an early study stage.

> "To make in deep documentary researches on a specific subject is interesting sometime, but this is not what we are asked for at our level. Actually it is very blunt what we are asked for. We have to add this or that element in our work, but nothing more. It is not needed, it is not what the professors asked us, I think that an in-depth research would not increase my final scores" (Psychology student, second year).

Considered as interesting or not, as far as students do not perceived the usefulness to multiply their research strategies to pass their year, they will not do it:

> "Sure, to master and control these tools is a plus, an added value; nevertheless I do not really see the usefulness to mobilise these technologies, since the library search engine provides me with the needed information to achieve the small works I am asked for" (History student, first year).

This position echoed the very students' pragmatic attitude already underlined above in other academic circumstances, which seems to be then a recurrent one among students. The following quote confirmed this trend:

> "For my work on the construction of the historical knowledge I found a very good book, I think I need nothing else. The book I have chosen is quite interesting and it deals with all the information I might need. What's for to multiply the sources of information, this would puzzle my work rather than simplify it" (History student, first year).

When, in contrast, senior students had to deliver multiple research works and final assignments, they were forced to address their attention to multiple sources to maximize their information gathering capacity and found then interesting to have learned using all these varied information tools:

> "I think that it is important to know all these research tools, now that I have to undergo my huge work in sociology. It is my first big academic work. If I didn't know how to master the tools, it would have been hard for to sort it out" (Social sciences student, first year).

Another student in last year expressed:

> "I think that it is a good thing to learn how to use all these databases during our fourth year, because we have our final work this year. To master all these tools help students to make their final work" (Information and communication student, fourth year).

These data tend to show that students not only diversify their sources of information as time goes by but that some of them also deepen their seeking behaviour. Therefore, as well as the discipline, the seniority can be read as a 'contextual constraint' driving students to deliver multiple works and final assignments and as a consequence forcing them to address their attention to multiple sources to maximize their information gathering capacity. At the same time, seniority is equivalent of experience and increased info-seeking know-how. Indeed, the latter students' tribe has learned during their time at the university via information-seeking courses and practices to manage and master different resources as well as to perform a more structured and articulated multi sources strategy.

6. Conclusions

This empirical study on the students' use of ICT takes as observation point the students' fence of the barricade and it examined the place of the Internet in the day-to-day academic students' lives. In particular, it explored the students' information behaviour patterns (for academic duties) to better enlighten the place and the role of electronic-based information resources compared to more 'traditional' and 'informal' sources and channels. Within this vein, the study questions the influence of academic disciplines and the year of study as potential moulding factors of students' information seeking strategies.

Quantitative as well as qualitative data results revealed that students have fully integrated ICT in their life but in a reasonable and moderate way, without showing any 'abuse' of 'addiction' to the medium.

Results also showed that, even though undergraduates across various disciplines made a regular use of the Internet when confronted with academic reports, they perform limited specific kind of use. The Internet appeared to be an important source when facing an entirely new topic and acts as a trigger for further research. It also appears to be very appreciated to provide complementary punctual information whatever the field of study.

Nevertheless, this medium is relatively forsaken when students had to seek in-depth information for university due to notably the perceived lack of scientific authority of Internet resources compared to the library ones in the academic environment. Although both hard and soft sciences disciplines implied a mix of different information-seeking strategies, there were differences in the relative importance given to the different kind of information resources (electronic-based and printed-based resources) and in the searching practices of the ones and the others. Students shaped their information seeking strategies in a pragmatic way, according with what can be defined as a 'goodness of fit' criteria taking into account the suitability of the tool with disciplinary contents and contents related constraints. Therefore, hard sciences students showed a strong preference for the Internet as an information resource (without neglecting books and scientific journals); whereas soft sciences students were more 'literate-print-based-oriented' (without neglecting the Internet).

The hard and soft contraposition gives an insight of the understanding of the discipline effect extent on 'traditional' studying behaviour such as looking for information, in terms of preference and variety of sources. For similarly context-dependent constraints, the seniority emerges as well as an important crafting factor on the students' information source selection; still, the disciplinary effect was rather reinforced by the seniority.

All in all, these findings show that students' information seeking patterns seemed to be far beyond the simple and univocal use and 'abuse' of the Web, replacing and supplanting traditional or informal resources. Via the integration of different tools (the library, the mates, the teaching staff, etc.), students built, then, an information seeking strategy, from a realistic point of view, which corresponds more to a mosaic of practices than to a monochrome paint where one main source has replaced the others in an uncritical way.

From an overall perspective, our data show then that students' use (and non use) of the Internet for academic purposes seemed to be a more sensible and strategic response to context short- or longer-term university requirements than a simply question of students' knowledge and skills deficiencies. Students' ICT use in general and their information seeking strategies in particular are then 'inscribed' in an economy of work in a whole.

This picture of the empowered and pragmatic student who embeds ICT use in his/her personal economy of work and time falls in line with the wider portrayal of the contemporary students daily life depicted in the current studies on the subject. (McInnis, 2004). 'New' students/consumers have been indeed described as actors mainly performing an instrumental and utilitarian approach to the university, combining often their role of student with other both leisure and/or working activities. (Erlich, 1998; Moscati, 2004).

This empirical study has then highlighted a 'reality' of ICT use – and of information literacy patterns in particular – more complex and subtle than popular and political discourses generally portray. Therefore, we would argue for a more thoughtful approach to the study of patterns of ICT usages by undergraduate students, taking into account their multicolored and variegated context of life and study. In other words, a 'one-size-fits-all' model of delivering instruction for information literacy would lead to inefficiencies because not corresponding to real needs, expectations and requirements students have.

Finally, we posit here for a ground rooted analysis of the student's practices, and we underline the importance of a descriptive approach to the question. New researches should then take into account different concerns affecting the way and conditions – in terms of finalities, purposes, needs and cultural backgrounds, incentives and disincentives – of the adoption and diffusion of these tools in education.

References

Abram S. and J. Luther (2004), "Born with the chip", *Library Journal*, 129(8), pp. 34-37.

Bijker W. and J. Law (1994), *Shaping Technology/Building Society: Studies in Socio-Technical Change*, MIT Press, Cambridge.

Brown C.M. (1999), "Information seeking behaviour of scientists in the electronic age: astronomers, chemists, mathematicians, and physicists", *Journal of the American Society for Information Science*, 50(10), pp. 929-943.

Cuban L. (1986), *Teachers and Machines: The Classroom Use of Technology since 1920*, Teachers College Press, New York.

Cuban L. (2001), *Oversold and Underused. Computers in the Classroom,* Mass., Harvard University Press, London, Cambridge.

Divleko J. and L. Gottlieb (2002), "Print Sources in an Electronic Age: A Vital Part of the Research Process for undergraduate Students", *The Journal of Academic Librarianship*, 28(6), pp. 381-392.

Dutton W. and D.B. Loader (Eds.) (2002), *New Media in Higher Education and Learning*, Routledge, London.

Erlich V. (2004), "The New Students. The Studies and Social Life of French University Students in a Context of Mass Higher Education", *European Journal of Education,* 39(4), pp. 284-293.

Feenberg A. (2004), *(Re)penser la Technique. Vers une Technologie Démocratique,* La Découverte/ M.A.U.S.S., Paris.

Finkelstein M.J., C. Francess, F.I. Jewett and B. Scholz (2000), *Dollars, Distance, and Online Education*, Oryx Press, Phoenix.

Flick U. (1998), *An Introduction to Qualitative Research*, Sage, London.

Hara N. and R. Kling (2002), "Students' difficulties in a Web-based distance education course" In: W.H. Dutton and B.D. Loader (Eds.), *Digital Academe. The New Media and Institutions of Higher Education and Learning*, Routledge, London, pp. 62-84.

Kling R. (2000), "Learning about Information Technologies and Social Change: the Contribution of Social Informatics", *The Information Society*, 16(3), pp. 217-232.

Kling R. and G. McKim (2000), "Not just a matter of time: Field differences and the shaping of electronic media in supporting scientific communication", *Journal of the American Society for Information Science and Technology*, 51(14), pp. 1306-1320.

Lahire B. (1997), Les Manières d'Etudier, *Les Cahiers de l'OVE*, 2, La Documentation Française, Paris.

Lahire B. (1998), "Matrices disciplinaires de socialisation et lectures étudiantes", *Bulletin des bibliothèques de France*, 43(5), pp. 58-61.

Lardelier P. (2006), *Le pouce et la souris. Enquête sur la culture numérique des ados*, Fayard, Paris.

MacKenzie D. and J. Wajcman (Eds.) (1996), *The Social Shaping of Technology*, Open University Press, Philadelphia.

Majid S. and A. Tee Tan (2002), "Usage of information resources by computer engineering students: a case study at Nanyang Technical University", *Online Information Review*, 26(5), pp. 318-325.

McInnis C. (2004), "Studies of Student life: an Overview", *European Journal of Education*, 39(4), pp. 294-300.

Millet M. (2003), *Les étudiants et le travail intellectuel*, PUL, Lyon.

Moscati R. (2004), Editorial, *European Journal of Education*, 39(4), pp. 279-283.

Erlich V. (1998), *Les Nouveaux Etudiants. Un Groupe Social en Mutation*, Armand Colin, Paris.

Pelletier C. (2005), "New Technologies, New Identities: The University in the Informational Age" In: R. Land and S. Bayne (Eds.) *Education in Cyberspace,* Routledge, London, pp. 9-11.

ROBINS K. and F. WEBSTER (Eds.) (2002), *The virtual university? Knowledge, Markets and Management*, Oxford University Press, Oxford.

SELWYN N. (2000), "Researching computers and education – glimpses of the wider picture", *Computers & Education*, 34, pp. 93-101.

SELWYN N. (2002), *Telling Tales on Technology. Qualitative Studies of Technology and Education*, Ashgate Publishing Limited, Hampshire.

SELWYN N. (2003), "The Effect Apart from Technology: Understanding the People's Non-Use of Information and Communication Technologies in Everyday Life", *Technology in Society*, 25, pp. 99-116.

SELWYN N. (2007), "The use of computer technology in university teaching and learning: a critical perspective", *Journal of Computer Assisted Learning*, 23, pp. 83-94.

SELWYN N., S. GORARD and J. FURLONG (2005), *Adult learning in the Digital Age. Information Technologies and the Learning Society*, Routledge, London.

SLAOUTI D. (2002), "The World Wide Web for academic purposes: old study skills for new?", *English for Specific Purposes*, pp. 105-124.

STENSAKER B., P. MAASSEN, M. BORGAN, M. OFTEBRO, and B. KARSETH (2007), "Use, updating and integration of ICT in higher education: Linking purpose people and pedagogy", *Higher Education*, 54, pp. 417-433.

TALJA S. and H. MAULA (2003), "Reasons for the use and non-use of electronic journals and data bases", *Journal of Documentation*, 59(6), pp. 25-35.

WHITMIRE E. (2002), "Disciplinary Differences and Undergraduates' Information-Seeking Behavior", *Journal of the American Society for Information Science and Technology*, 53(8), pp. 631-638.

WILLIAMS R. and D. EDGE (1996), "The Social Shaping of Technology" In: W.H. Dutton and M. Peltu (Eds.), *Information and Communication Technologies: Visions and Realities*, Oxford University Press, Oxford, pp. 53-68.

Predicting academic performance by data mining methods

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Summary

Academic failure among first-year university students has long fuelled a large number of debates. Many educational psychologists have tried to understand and then explain it. Many statisticians have tried to foresee it.

Our research aims to classify, as early in the academic year as possible, students into three groups: the 'low-risk' students, who have a high probability of succeeding, the 'medium-risk' students, who may succeed thanks to the measures taken by the university, and the 'high-risk' students, who have a high probability of failing (or dropping out).

This article describes our methodology and provides the most significant variables correlated to academic success among all the questions asked to 533 first-year university students during the month of November of academic year 2003-04. Finally, it presents the results of the application of discriminant analysis, neural networks, random forests and decision trees aimed at predicting those students' academic success.

1. Introduction

In many countries, universities are more and more frequently faced with saturated and highly competitive markets. In this perspective, the student – the university's essential resource – is at the centre of the university's preoccupations and initiatives. The university must thus take its students' needs into account more than ever before: Who are they? How can they be attracted? How can they be retained in the university system for as long as possible without reducing the quality of their studies? What is the cost-benefit ratio for a student who succeeds in his/her first year? What is the cost-benefit ratio for a student who succeeds thanks to a number

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of measures taken by the university? These and other questions need to be seriously considered.

When we analysed the results of first-year students in Belgian French-speaking universities, we found that about 60 % of first-generation[2] students fail or drop out. Droesbeke *et al*. (2001) observed stability in terms of success, repeat and drop-out rates over a period of 10 years. They showed that the success rate of first-generation secondary students was close to 41 %, while their repeat rate was approximately 26 % and their drop-out rate 33 %. Given these figures, appropriate action should be taken to reduce the worrying economic, social and human costs involved in such a high level of failure in the first year at university. For many years, most Belgian universities have provided supplementary activities to the normal first-year program (computer-assisted teaching, tutorials, etc.) in order to fill in the gaps for 'failing' students, particularly after the January examination period.

Our main objective is to classify students into three groups: 'low-risk' students, with a high probability of succeeding; 'medium-risk' students, who may succeed if the university takes appropriate measures; and 'high-risk' students, who have a high probability of failing or dropping out. We thus needed to create a database in which every student was described according to a range of criteria or characteristics, such as their age, their parents' level of education, their perception of the university environment, etc. To determine the factors to be taken into account we used a model adapted from Philippe Parmentier (1994). With all these explanatory variables, our objective was to determine whether it was possible to predict, at the beginning of the academic year, the group to which a student belonged, so as to provide an optimal distribution of teaching resources to curb academic failure. To do this, we used several methods: decision trees, neural networks and a linear discriminant analysis, and compared the differing results.

At the beginning of the academic year 2003/04 we distributed a questionnaire at three Belgian universities. The exercise was repeated the following year. As a result we will be able to establish correspondences and divergences between the predictive models obtained in different institutions. Students were asked to complete the questionnaires during a class, which means that the non-response rate corresponds to the students' attendance rate. In the first year, and particularly at the beginning of the year, the attendance rate is extremely high, at close to 93 %. Our sample contained 533 students registered in these three Belgian universities. Some 375 variables were available for each of them, a number which clearly had to be reduced for any statistical or mathematical treatment. The decision variable used for the construction of our models is an ordinal variable with three modalities, built *a posteriori* by grouping students according to their academic performance.

First of all, we will present the methodology that we adopted. Then, we will describe the data and present the results obtained by the different data mining methods. Finally, we will compare their performance with a linear discriminant analysis.

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[2] "First-generation students" means that they are not repeating the year.

2. Methodology

Many studies in a variety of countries (Ardila, 2001; Betts and Morell, 1999; Boxus, 1993; Busato *et al.*, 1999, 2000; Chidolue, 1996; Cohn *et al.*, 2004; Furnham *et al.*, 1999; Gallagher, 1996; Garton *et al.*, 2002; King, 2000; Minnaert and Janssen, 1999; Parmentier, 1994) have attempted to explain academic performance and to predict success or failure at university. The results have highlighted a series of explanatory factors associated with the students' background.

We started by consulting the abundant literature on education in order to establish a list of factors that professionals believe to be causes (or indices) of success and failure in the first academic year. Next, we targeted a set of factors to be taken into account. This was based on a model used by Parmentier (1994), who showed that students' intermediate and final academic performance is influenced by the interaction of three sets of factors. The first group of factors are structural or stable variables, while the other two are composed of process or changing factors. The first set includes everything related to the personal history of the student (age, gender, socio-economic background, academic record, etc.). The second can be interpreted as the expression of students' involvement in their studies (participation in optional activities, meetings with lecturers or tutors to ask questions or to obtain feedback on examinations results, etc.). The final set of factors groups all the students' perceptions (their views on their academic context, professors, courses, etc.).

Our second step was to create a questionnaire to collect a large amount of information from students. In November 2003, we distributed this questionnaire to first-year students in three French-speaking universities in Belgium. In November 2004, we distributed the same questionnaires at the same Belgian universities and also in a French university. The data presented here only refer to the 2003/04 cohort. The sample consists of 227 students of management science or political science in their first year at the Catholic University of Mons (FUCaM), 151 civil engineering students at the Faculté Polytechnique in Mons (FPMs) and 155 bio-engineering students at the Faculté Universitaire des Sciences Agronomiques in Gembloux (FSAGx). The students of management and political science and bio-engineering had successfully completed their secondary studies (the only requirement for entering to these faculties in Belgium), while the civil engineering students had passed an entry examination for their course.

Based on the questionnaires, a database was constructed in which each student is described according to criteria or attributes (explanatory variables X) such as age, education level of his/her parents, perceptions of the university world. By using mid-year and end-of-year results we assign each student to a risk-of-failure category (high, medium or low risk of failure) and so create the dependent variable Y. After selecting the most appropriate predictors (X), in terms of their correlation with Y, we estimate a prediction model to target students who need to be helped. To achieve this it is necessary to extract information from the database that allows us to profile these students. This is done using data mining and statistical methods: decision trees, neural networks and linear discriminant analysis. Regression methods are not the most appropriate here, because there are three possible values for Y. A *post hoc* study has shown that logistical regressions are less effective than discriminant analyses for data such as this, which is highly interdependent.

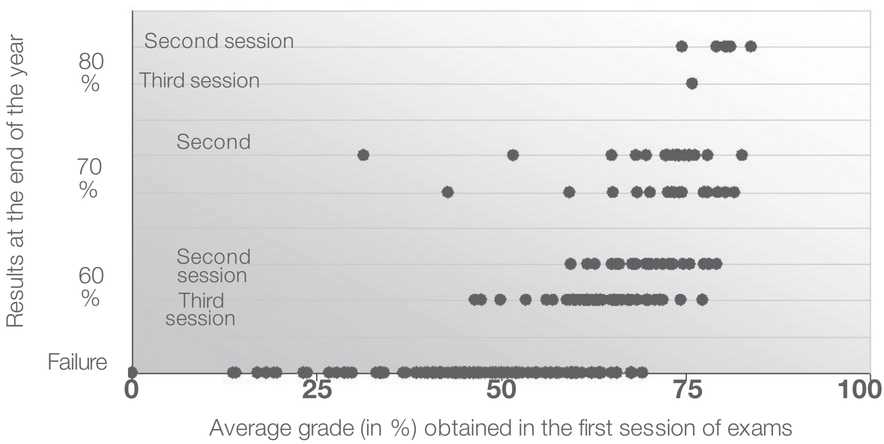
The aim is to enable these students to be given priority in the allocation of the limited resources available for teaching support (tutorial by an older student, private tutorial by a lecturer, etc.). Before analysing the data, we should note that a model with good rates of classification is of no particular interest to us; only its predictive power for new individuals is truly significant. For this reason we developed the model using data on no more than 70 % of the students, keeping the remaining 30 % for the validation phase.

3. Data

The questionnaire comprised 42 questions or question-series, almost all of them closed. From this we extracted 148 variables, most of which were either binary or coded into 5 response categories, although some were percentages. Hence each student who completed the survey would be represented by 375 variables (potential predictors, X) in the database. To this can be added the dependent variable (Y). If we wish to explain academic success at the end of first year, the outcome is not available until the September following the administration of the questionnaire, since we have to wait and see if the student proceeds into second year. Our objective is to classify students, **before** the first session of exams into three groups according to their probability of success. This will allow students who require aid to be identified, and specific remedial action to be undertaken.

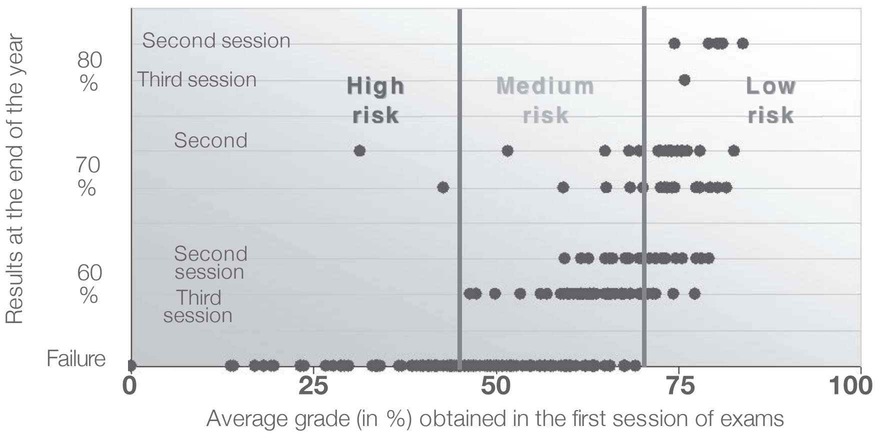
Figure 1 shows how the average mark obtained by a student in the first (January) session of examinations relates to their academic rank at the end of the year. Each student is represented by a point in the figure.

Figure 1 Relation between the results obtained in the first session of exams and in the end of the year



Two contrasting groups of students can be clearly distinguished: those who obtained an average mark of less than 45 % in the January session, all except two of whom failed at the end of the year; and those who obtained an average of more than 70 % in January, who all passed at the end of the year. On the basis of this distinction we created the dependent variable Y (the decision variable) that represents the risk-of-failure category for each student (Figure 2). This variable had to reflect not only the final results of the students but also their capacity to develop during the year.

Figure 2 An example of the way the decision variable is constructed



At the level of the variables themselves, a preliminary study carried out by Vandamme *et al.* (2004) showed how variables which are not correlated with the dependent variable can damage predictions in this field. An analysis of the correlations was thus carried out to select the predictors (X) with the highest correlation with the dependent variable Y from among the numerous possibilities. The rest of this chapter is devoted to a description, using Parmentier's (1994) classification, of the variables that are most highly correlated with Y. The value of the correlation coefficient between each explanatory variable and the decision variable[3] is indicated in brackets. For the continuous variables, the value of the correlation coefficient is followed by one, two or three stars to indicate whether the test of significance showed this relationship to be significant, very significant or highly significant. For discrete variables, the appropriate test of significance is a chi-square test, and the p-value of this test is indicated by stars alongside the value of the correlation coefficient.

A. *Personal history of the student*

It comes as no surprise that the variables which relate to students' scholastic history and their socio-economic background have the highest correlation coefficients. Thus, the students' average grade in the final year of secondary education was most highly correlated with chance of success ($r = 0.337^{***}$) among all those we tested. The number of hours of mathematics in the final year of secondary educa-

[3] We have coded the dependent variable (Y) as 1 for High risk, 2 for Medium risk and 3 for Low risk.

tion (r = 0.313***) was also highly significantly related to university success. Not having to finance their own studies (r = 0.162*), not having followed courses in economic sciences or social sciences in secondary school (r = 0.157*), not being older than average (which is probably representative of school failure in the past) (r = 0.152*), and even not smoking (r = 0.177**) are all factors that significantly influence university success. Conversely, the sex of the student, the highest educational level obtained by his or her parents, parental occupation and marital status, and the number of siblings (whether older or younger, with or without higher education) were not significantly related to success at university.

B. Student behaviour

The number of hours which the student claims to attend class was highly correlated with academic success (r = 0.250***). The less likely students were to mention regularly missing classes, the higher their chances of success (r = 0.164*). It is a bad idea for a student to miss even those classes that are least well-attended by fellow students (r = 0.134***).

It is advisable for students to thoroughly understand the material they are studying (r = 0.165**) and not simply to dwell on those aspects that interest them (r = 0.159***). Here Entwistle's (1988) theory of the various ways in which students study may be relevant. Finally, let us note that students who understand that the course requires regular homework also tend to be those who succeed (r = 0.143***).

All these factors are strongly related to success, unlike variables relating to students' extra-curricular activities. Whether students participate in student-organised activities, have undergone initiation ceremonies[4], spend time pursuing hobbies or with their families are not significantly correlated with success.

Before concluding this section on student behaviour and the implication of this for their studies, we should note that we adapted Laurent and Kapferer's (1986) scale (well-known in marketing) to this field. Thus, if involvement is defined as a non-observable state of motivation, excitation or interest created by an object or a specific situation and involving behaviour (Rothschild, 1984), Laurent and Kapferer suggest that all discussions of involvement in social psychology or in marketing are discussions of one or more variables which they identify as being the causes of the involvement. By adapting these involvement factors to the world of the university, we obtained a series of 16 questions which are closely related to Laurent and Kapferer's initial scale. This series of questions thus gives us another way of measuring students' involvement, and the resulting variable is also highly correlated with university success.

C. Students' perceptions

This last group of parameters, students' perceptions, is more subjective than tangible. However, some of the variables in this category were also highly significant. The student's confidence in his or her own abilities was the most important. In fact,

[4] It's a feature of student life in Belgium, the old students celebrate activities of welcome to the new students.

Zimmerman *et al.* (1992) has already shown that a student who has a lot of confidence in his/her capacities is more persistent, more productive and more motivated by academic studies than other students. We found that the higher a student rates his or her own chances of success, the greater the probability that he or she actually succeeds (r = 0.326***). In the same way, it is better not to find the course too difficult from the beginning of the year (r = 0.150*) or to think that you were badly prepared for higher education (r = 0.182*). Students who, in November, felt that they had chosen well in enrolling at their university (r = 0.182***), those who did not overestimate the study time necessary for success (r = 0.159*) and those who preferred group work to working alone (r = 0.232***) were those most likely to succeed a few months later. On the other hand, the variables that were most significant in explaining success or failure did not relate to the students' perception of their environment nor, to a large extent, to their perception of their academic context.

D. Summary

One variable in five proved to be significantly related to university performance, and more than a third of these were very strongly related. The highest correlations concerned attendance at courses, estimated chance of success, previous academic experience (particularly in mathematics), and study skills. Factors with a significant relation to success were found in each of the three groups of variables. This suggests that even though many structural factors are fixed before entry to university, nothing is finalised and changing process factors also play a large part in academic performance.

It should be emphasised that these measurements were carried out on all 533 students in our sample and the values reported so far are the averages for the three universities considered. However, large differences exist between the three sub-samples corresponding to the three universities. Thus, the variable with the highest average overall correlation was only third, sixth and nineteenth in the list of the most-highly correlated variables in the three sub-samples; the variable for the student's average achievement in the final year of secondary schooling was the most highly correlated with success in two of the three courses, but came out 167th in the third. There are many such examples. They are confirmed by the relationship between the decision variable and a nominal variable for the university attended, which gave a chi-square of 82 with 6 degrees of freedom, corresponding to a p-value of 10^{-15}. For reasons of confidentiality, however, we are not able to provide details of the results obtained for each institution separately.

E. Descriptive statistics

Table 1 shows the means and standard deviations of the nine variables which are most highly correlated with the dependent variable for each risk-of-failure group (for the three universities taken together). When Table 1 is analysed it is evident that the mean values for the high-risk group are less good than those for the medium-risk group, which in turn are less good than in the low-risk group.

Table 1 Descriptive statistics for the most important variables

Variables	*Description*
%succW	Chance of success that the students believe that they have, weighted upward or downwards depending on the pessimistic or optimistic grade that the student perceives himself
Rank	Whether students were first or last in their class at secondary school
%succ	Chance of success that the students believe that they have
AvGrad	Average grade in final year of secondary school (evaluated on a scale)
MatLang	Hours of mathematics and languages taken in final year of secondary school
Pass	Whether students think they will or will not pass the year
Wrkgr	Whether students prefer to work in groups or alone
HrMaths	Hours of mathematics taken in final year of secondary school
Attend	Proportion of courses the student attends

		%succW	*Rank*	*%succ*	*AvGrad*	*MatLang*	*Pass*	*Wrkgr*	*HrMaths*	*Attend*
High risk	mean	50.96	2.43	56.11	2.41	21.21	3.70	1.90	5.51	84.73
	s.d.	16.22	0.88	14.96	0.96	5.42	0.46	1.30	1.74	17.52
Medium risk	mean	57.41	2.73	62.94	2.70	22.39	3.85	2.43	5.87	91.30
	s.d.	14.41	0.81	14.73	1.06	4.91	0.36	1.20	1.53	10.56
Low risk	mean	63.47	3.18	68.51	3.16	24.44	3.92	2.65	6.90	93.39
	s.d.	13.11	0.75	12.86	0.95	3.60	0.28	1.12	1.84	9.58

4. Results

The objective of this study was to determine whether it is possible to predict the decision variable from the explanatory variables which we retained in the model (following suppression of the variables which were not significantly related to the decision variable itself) and which characterise the 533 first-year university students before November of their first term. To do this, we used several methods: decision trees, neural networks and a linear discriminant analysis[5], and compared the results obtained from each of them. In order to validate the results, we estimated our model using a 70 % subset of the data file and kept the remaining 30 % as a validation set for the models obtained from the estimation subset.

When we keep 30 % of the sample for validation purpose we reduce drastically the knowledge base available to construct an adequate model.. This is the price that we accept to pay in order to ensure via the validation step that our model is not just a correct synthesis of a particular dataset. Our goal is not only to obtain a high internal

[5] See the Appendix for further explanation of the different methods used.

accuracy rate but also to maximise the external accuracy rate. That means that the model must also allow us to classify new students correctly.

A. *Decision tree*

Decision trees (Rakotomalala, 1997) are powerful and popular tools for classification and prediction. A decision tree consists of nodes and branches. The starting node is usually referred as the root node. To determine the root node we calculate which attribute will most exactly classify the objects (here students) according to the values of the decision variable. In this way, the tree branches right or left to another node, where the procedure is repeated. For any tree, all paths lead to a terminal node (sometimes referred to as a leaf) corresponding to a decision rule that is a conjunction (AND) of various tests. A decision is then made on the assignment to a class.

Decision-tree-building algorithms always begin by trying to find the test which does the best job of splitting the data among the desired categories. At each subsequent level the subsets created by the preceding split are themselves split according to whatever rule works best for them. The tree continues to grow until it is no longer possible to find ways of splitting the data. Nodes become terminal and cannot be split further when all members of the sample belong to one class. One of the most important issues in developing a decision tree is the choice of the attribute that best discriminates among the target classes. Therefore, the way of finding the attribute that produces the best split in the data is the one of the main differences between the various decision-tree-building algorithms. For example, CART (Breiman *et al.*, 1984), which is one of the most popular algorithms, uses an index of diversity (the Gini index). However, ID3 (Quinlan, 1979) utilises entropy as a way to evaluate a potential splitter.

Another area in which decision-tree-building algorithms differ substantially, is in their approach to reducing the size of the tree. As described above, the decision tree keeps growing as long as new splits can be found that improve its ability to separate the records into classes. This can lead to a null apparent error rate (often called overfitting) as the model is fitted exactly to the development data set. When new cases are used in the same model, the true error rate will be much higher. This means that it is often essential to find a sub-tree that yields better predictions in the general case. Two main approaches have been used for this purpose: limiting tree growth (also called pre-pruning) and pruning the existing tree (post-pruning). In the first approach, the aim is to stop the tree growing when further splits are unlikely to be significant (as measured by a standard statistical test, such as a chi-squared test). Unfortunately, limiting tree growth by applying a significance test is generally not the best approach to reducing overfitting; empirical research has shown that post-pruning is frequently superior. Post-pruning starts with a tree that is already fully expanded. Working from the bottom of the tree, the weakest branches are then cut off until no weak branches remain. Different methods of pruning (for example reduced-error pruning and cost-complexity pruning) exist.

The strengths and weaknesses of decision tree are numerous. The strengths are the ability to generate comprehensible rules, to handle both continuous and categorical variables, and to provide a clear indication of which attributes are the most important for prediction and classification. On the other hand, decision tree are unable to predict the value of a continuous variable and the tree can be transformed into bush if there are too many nodes or too many classes. Moreover, decision tree algorithms only consider one field at a time. This leads to rectangular classification boxes which may not correspond well to the actual distribution of records in the decision space.

We used the SAS/Enterprise Miner software to build a decision tree. As discussed above, different algorithms can be used to build a decision tree. In this case we chose to build our tree on the basis of Shannon's entropy and the ID3 algorithm. We obtained a tree which has the advantage of being particularly simple to interpret: the classification of students uses only five variables. In decreasing order of importance these are students' weekly attendance at courses, their feeling of having chosen well by registering at this university, and three variables on the reasons that students decided to register at university or begin this type of study.

Table 2 The results of the validation for the decision tree

		Predictions			
		High risk	Medium risk	Low risk	Total
Actual	High risk	**48.65 %**	10.81 %	40.54 %	100 %
	Medium risk	33.85 %	**18.46 %**	47.69 %	100 %
	Low risk	22.41 %	17.24 %	**60.34 %**	100 %

However, as shown in Table 2, the proportion of correct predictions in the model validation phase are not very good: only 48.65 % of the students in the high risk category were correctly classified by the elaborated tree, and for the medium risk students this figure fell even further (18.46 %). However 60.34 % of the students at low risk of failure were correctly classified. For the extreme classes, the decision tree managed reasonably well, but the predictions for students at 'medium risk' were poor (although this is the most densely populated class, containing 40 % of the students, compared to 27 % in the high risk group and 33 % in the low risk category). Overall, the classification was only 40.63 % correct.

Table 2 contains the results for the validation sample. However, we have already noted that there were large differences between the students on the different courses, and it would therefore be more logical to construct three separate decision trees. In doing so, we have to use a smaller number of students for the construction and validation of the trees, but nevertheless we get better results in terms of the rates of correct classification: 46.66 %, 51.47 % and 61.70 % for the three institutions in our sample. The reduction in the number of cases available for constructing the decision tree thus seems to be less problematic than the heterogeneity of the students registered on the various courses.

B. Neural networks

Neural networks (Dreyfus *et al.*, 2002) are a statistical tool which is frequently used for classification, estimation and prediction. The aim is to categorise the working of the human brain by an iterative algorithm. A neural network may be defined as a collection of units or neurons that function in parallel in order to execute a common global task. These units are interconnected by links which allow communication between the individual units. Each link is associated with a value, a weight (sometimes called a synaptic weight, with reference to biology).

The units combine their inputs to give just one output value, obtained by means of a unit activation function. This function is made up of two parts. The first is an aggregation function, which combines the various input values; the most commonly used aggregation function is a weighted sum of inputs. The second part is a transfer function, which transfers the value resulting from the aggregation function to the neuron output. The most frequently used transfer functions include sigmoid, linear and hyperbolic tangent functions. Many types of neural networks have been proposed in the literature, but the best-known is undoubtedly the multi-layer perceptron (MLP). This is a feed-forward type of neural network, which, as its name suggests, is arranged in layers. MLPs thus typically comprise an input layer (input variables), one or more hidden layers (each made up of one or more neurons that combine their inputs and generate an output that is passed on to the neurons in the next layer), and an output layer.

On the basis of our training set (containing data on 70 % of the students), we built a model by means of the neural networks procedure in SAS/Enterprise Mining. The final model is a multi-layer perceptron with a hyperbolic tangent as its activation function, one hidden layer containing three neurons, and one exit neuron to carry the predictions to our decision variable. Other neural network models were also tested but gave less good results. Applying a selection procedure for variables upstream of the neural networks model allowed us to determine which variables would be used in the model and the number of entry neurons. Some 23 variables were selected which cover all three categories of factors defined by Parmentier. For example, the student's age, the average percentage of classes attended during one week, a series of measurements of motivations in choosing a university, the number of hours of mathematics studied at secondary level, and the average mark at the end of secondary school were included in the model.

Table 3 The results of the validation for neural networks

		Predictions			
		High risk	Medium risk	Low risk	Total
Actual	High risk	**45.95 %**	40.54 %	13.51 %	100 %
	Medium risk	30.88 %	**47.06 %**	22.06 %	100 %
	Low risk	00.00 %	38.18 %	**61.82 %**	100 %

Table 3 shows that the rates of correct classification are slightly better than in Table 2, but are still not particularly impressive. Overall, the total percentage of students classified correctly by the neural networks approach was 51.88 %.

C. Linear discriminant analysis

Discriminant analysis is a method of classifying an individual into one of *g* groups to where he or she best belongs (Palm, 1999). To do this, the method determines an allocation rule based on *p* variables which characterise each individual to be classified. This allocation rule is defined as a function of *g* samples taken from the groups. In general there are several solutions to defining the classification rule by which each new individual is assigned to one of the *g* classes.

By way of comparison with more recent methods such as decision trees and neural networks, it is interesting to look at the results (Table 4) of a linear discriminant analysis (Palm, 1999), where the preliminary selection of variables has been made with a stepwise strategy (using the SAS software). The variables which were selected and retained for the construction of the discriminant functions almost match those chosen by the neural networks.

Table 4 The results of the validation for the linear discriminant analysis

		Predictions			
		High risk	Medium risk	Low risk	Total
Actual	High risk	**45.95 %**	40.54 %	13.51 %	100 %
	Medium risk	22.06 %	**57.35 %**	20.59 %	100 %
	Low risk	1.82 %	30.91 %	**67.27 %**	100 %

The results presented in Table 4 reveal an overall total correct classification rate of 57.35 %. This is 20 – 30 % worse than would have been observed if we had been interested in a binary success/failure variable. Nevertheless it is the least bad result of the three methods.

5. Conclusions and perspectives

We found that 20 % of our variables showed significant correlations with academic success. These variables were found in each of the categories proposed by Philippe Parmentier (1994). The same is true for the variables used in the three methods of prediction that we compared in this research. Thus the theoretical model on which we based our research seems to be quite appropriate.

Our aim here was not simply to predict the success or failure of the students. If that were the aim, we could have achieved a rate of correct classification of over 80 %. The difficulty is to classify the students into three groups, before the first university examinations, so that we can offer help to the intermediate group of students. Clearly this should be done before they are demotivated by any early failure

Our results show that the rates of prediction obtained by the three models in the validation phase were not particularly good. There were large disparities between the three universities from which our sample was taken, and combining the data from these groups lowered the predictive power of each of the three methods. However, discriminant analysis, and to a lesser extent neural networks, seem to be able to produce interesting results. In future we aim to increase the size of our samples from each university by incorporating data from an additional academic year.

Appendix

I. Technical background to the different methods of prediction

I.1. Decision tree

We have chosen to build our tree on the basis of Shannon's entropy and the ID3 algorithm. Shannon's entropy is one of the most-frequently used measures in tree construction. It's performance is a function of the purity of the node, which characterises the degree to which the objects in the node are mixed.

Shannon's entropy, *E(*S) for the training dataset S, is defined as

$$E(S) = -\sum_{k=1}^{K} p_k \log_2 p_k$$

where *p*k is the proportion of training dataset with the value k for this attribute.

The ID3 algorithm uses the information gain (i.e. the reduction in entropy caused by the separation of the dataset according to this attribute). The information gain *G(S,A)* is defined as

$$\mathrm{G(S,A)} \equiv \mathrm{E(S)} - \sum_{Value(A)} \frac{|\mathrm{S_v}|}{|S|} E\left(S_v\right)$$

where *S* and *A* are the training dataset and the variable under consideration respectively. Value(A) are all the possible values of *A*, and *S*v is the subset of S for which A has the value *v*.

I.2. Neural networks

As already discussed, the output value of neural networks is obtained by means of an activation function that is made up of two parts: an aggregation function and a transfer function.

The aggregation function used is a weighted sum of inputs:

$$a_i = \sum_{j=1}^{n} w_{ij} x_j + \theta_i$$

For the transfer function we used a hyperbolic tangent to transfer the value from the aggregation function to the neuron output. This hyperbolic tangent is defined as

$$\tanh(x) = \frac{e^x - e^{-x}}{e^x + e^{-x}} = \frac{e^{2x} - 1}{e^{2x} + 1}$$

I.3. Linear discriminant analysis

For linear discriminant analysis we assume *g* normally distributed populations of *p* dimensions, with equal matrices, variances and covariances, from which *g* random, simple and independent samples have been taken. Then $\hat{m}_k$ are the vectors of the average of the *g* populations and $\hat{\Sigma}$ is the common matrix of variances and covariances, these parameters being estimated from the samples. For an individual, characterised by an observation vector xi, the density of the probability corresponding to the population h is

$$f_h(x_i) = \frac{1}{\sqrt{(2\neq)^p \left|\hat{\Sigma}\right|}} \exp\left(-\frac{1}{2} d_{hi}^2\right)$$

with

$$d_{hi}^2 = (x_i - m_h) \hat{\Sigma}^{-1} (x_i - m_h)$$

and, the probability *a posteriori* of membership of the h population is

$$\mathrm{P}\left(\mathrm{A}h \middle| x_i\right) = \frac{\exp\left(-\frac{1}{2} d_{hi}^2\right)}{\sum_{k=1}^{g} \exp\left(-\frac{1}{2} d_{ki}^2\right)}$$

If the probabilities are equal *a priori*, the individual i will be classified in the populations in which $fh(x_i)$ is maximal, d^2_{hi} is minimal, and $\mathrm{P}(\mathrm{A}h|x_i)$ is maximal.

I.4. Discriminating linear functions

Some $g(g–1)/2$ discriminating linear functions can be calculated that, equalised to a constant, determine $g(g–1)/2$ hyperplanes delimiting g areas to which the different populations considered can be associated. The starting point for determining the hyperplane separating two unspecified populations, h and l, is the bond between the density functions of the relative probabilities of these two populations. This is called the relation (bond) of resemblance, and is written as

$$L_{hl} = \frac{f_h(x)}{f_l(x)} = \frac{\left(1/\sqrt{(2\neq)^p |\Sigma|}\right)\exp\ -\frac{1}{2}(x - m_h)\ \Sigma^{-1}\ (x - m_h)}{\left(1/\sqrt{(2\neq)^p |\Sigma|}\right)\exp\ -\frac{1}{2}(x - m_l)\ \Sigma^{-1}\ (x - m_l)}$$

After simplification, and taking the logarithm of the expression, we obtain

$$\log_e\left(L_{hl}\right) = \left(m_h \Sigma^{-1} x - \frac{1}{2} m_h \Sigma^{-1} m_h\right) - \left(m_l \Sigma^{-1} x - \frac{1}{2} m_l \Sigma^{-1} m_l\right)$$

The vectors x that fulfil this expression belong to the hyperplane that separates the population h from the population l. The function

$$m_h \Sigma^{-1} x - \frac{1}{2} m_h \Sigma^{-1} m_h$$

is called the discriminating linear function of the population h, and the calculation for an individual allows this individual to be classified in the group for which the discriminating linear function is greatest.

References

ARDILA A. (2001), "Predictors of university academic performance in Colombia", *International Journal of Educational Research*, 35, pp. 411-417.

BETTS J.R., D. MORELL (1999), "The determinants of undergraduate grade point average: the relative importance of family background, high school resources, and peer group effects", *Journal of Human Resources*, 34/2 (Spring), pp. 268-293.

BOXUS E. (1993), *Réussites en candidatures*, Rapport du Conseil Interuniversitaire de la Communauté Française, Brussels.

BREIMAN L., J.H. FRIEDMAN, R. OLSHEN, C. STONE (1984), *Classification and Regression Trees*, Wadsworth International Group, Belmont.

BUSATO V.V., F.J. PRINS, J.J. ELSHOUT, C. HAMAKER (1999), "The relation between learning styles, the big five personality traits and achievement motivation in higher education", *Personality and Individual Differences*, 26, pp. 129-140.

BUSATO, V.V., F.J. PRINS, J.J. ELSHOUT, C. HAMAKER (2000), "Intellectual ability, learning style, personality, achievement motivation and academic success of psychology students in higher education", *Personality and Individual Differences*, 29, pp. 1057-1068.

CHIDOLUE M.E. (1996), "The relationship between teacher characteristics, learning environment and student achievement and attitude", *Studies in Educational Evaluation*, 22(3), pp. 263-274.

COHN E., S. COHN, D.C. BALCH, J. BRADLEY Jr. (2004), "Determinants of undergraduate GPAs: SAT scores, high-school GPA and high-school rank", *Economics of Education Review*, 23(6), pp. 577-586.

DREYFUS G., J.M. MARTINEZ, M. SAMUELIDES, M.B. GORDON, F. BADRAN, S. THIRIA, L. HERAULT (2002), *Réseaux de neurones*, Eyrolles, Paris.

DROESBEKE J.-J., I. HECQUET, C. WATTELAR (2001). *La population étudiante*, Editions de l'Université de Bruxelles, Brussels, http://digistore.bib.ulb.ac.be/2007/i9782800412719_000_f.pdf.

ENTWISTLE N. (1988), "Motivational factors in students' approaches to learning" In: R.R. Schmeck (Ed.), *Learning Strategies and Learning Styles*, Plenum, New York, pp. 21-51.

FURNHAM A., C.J. JACKSON, T. MILLER (1999), "Personality, learning style and work performance", *Personality and Individual Differences*, 27, pp. 1113-1122.

GALLAGHER D.J. (1996), "Personality, coping, and objective outcomes: extraversion, neuroticism, coping styles, and academic performance", *Personality and Individual Differences*, 21(3), pp. 421-429.

GARTON B.L., J.E. DYER, B.O. KING (2002), "Factors associated with the academic performance and retention of college agriculture students", *North American Colleges and Teachers of Agriculture Journal.*

KING A.R. (2000), "Relationships between CATI personality disorder variables and measures of academic performance", *Personality and Individual Differences*, 29, pp. 177-190.

LAURENT G., J.N. KAPFERER (1986), "Les profils d'implication", *Recherche et applications en marketing*, 1, pp. 41-57.

MINNAERT A., P.J. JANSSEN (1999), "The additive effect of regulatory activities on top of intelligence in relation to academic performance in higher education", *Learning and Instruction*, 9, pp. 77-91.

PALM R. (1999), "L'analyse discriminante décisionnelle: principes et application", *Notes stat. Inform. Gembloux*, 99(4), pp. 1-41.

PARMENTIER P. (1994), *La réussite des études universitaires: facteurs structurels et processuels de la performance académique en première année en médecine* (PhD thesis), Faculté de Psychologie et des Sciences de l'Education, Université Catholique de Louvain, Louvain.

QUINLAN J.R. (1979), *Discovering Rules by Induction from Large Collections of Examples*, Ed. Expert Systems in the Micro Electronic Age, Edinburgh University Press, Edinburgh.

RAKOTOMALALA R. (1997), *Graphes d'induction* (PhD thesis), Université Claude Bernard, Lyon.

ROTHSCHILD M.L. (1984), "Perspectives on involvement: current problems and future directions", *Advances in Consumer Research*, 11, pp. 216-217.

VANDAMME J.-P., N. MESKENS, A. ARTIBA (2004), "La réussite universitaire: méthodes et outils d'analyse utilisés depuis vingt ans", Paper presented at the 21st Congress of the AIPU, Marrakech, Morocco.

ZIMMERMAN B.J., A. BANDURA, M. MARTINEZ-PONS (1992), "Self-motivation for academic attainment: the role of self-efficacy beliefs and personal goal setting", *American Educational Research Journal*, 29(3), pp. 663-676.

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