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University Technology Transfer: How (in-)efficient are French universities?

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Abstract

This paper assesses the efficiency of the technology transfer operated by the French university system and its main determinants. The analysis is based on a detailed and original database of 51 TTOs, categorized by type of university, over the period 2003-2007. Overall, we find low-level of efficiency and both intra-category and inter-categories efficiency variation. The analysis of determinants shows that French TTOs efficiency depends extensively on the nature of the category (with universities specialised in science and engineering resulting the most efficient ones), on institutional and environmental characteristics. We found that both the seniority of TTO and size of the university have a positive effect. In terms of environmental variables, the intensity of R&D activity (both private and public) has a positive impact; however, in terms of growth rate, only the Private R&D activity seems to be the main driver. Lastly, having a medical school related to a hospital is a source of inefficiency.

Keywords: Technology Transfer Offices (TTOs), French University System, Technical Efficiency, DEA, Bootstrap

JEL Classification: C34; C44; D24

1. Introduction

In recent times, European universities are being asked to play an increasing number of roles and start learning how to compete (Deiaco *et al*. 2009) as a consequence of undergoing rapid changes in national systems of research and innovation and the economic conditions. This phenomenon is strictly correlated to the increased recognition and importance of the role of knowledge in creating economic wealth of countries, where universities find their central role. Universities are therefore gauging their prominent role, much more than the in past, as integral part of nations and firms' economic activities with the clear mission to create, renew and transfer knowledge.

Because of their broader role, European universities are called on to explain to several, and with different own interests, stakeholders how, whether and why their scientific knowledge and educational programmes are relevant to society. In such a framework, thinking strategically about technology transfer for university administrators might be the key of success. In the same way, the resources allocation decisions on the possible modes of technology transfer, namely licensing, start-ups, sponsored research and other mechanisms of technology transfer that are focused more directly on stimulating economic and regional development, such as incubators and science parks, should be based on strategic choices .

In the last decade, policy makers of advanced industrial nations, Europe included, started to formalize the mechanism of university-industry technology transfer through the systematic development of Technology Transfer Offices (TTOs). As today, the result is a profound interest in understanding "best practices" in university technology transfer by both practitioners and academic researchers. In particular, how productivity and efficiency of university technology transfer may be improved? What are the determinants of inefficiency differentials among university technology transfer activities of a country? How these differentials change according to the disciplinary mix of universities ?

There are numerous studies on the productivity or (in-)efficiency, estimated from indicators of outputs and inputs of university technology transfer (for a recent review see Siegel, 2007). Most of the available empirical evidence is based on US data while evidence on European countries is confined in a handful of papers, mostly due to lack of data. Interestingly, a recent policy paper, summarizing some evidence on European universities, suggested that "perhaps the most important conclusion for policy making at this stage is to invest more in data and analysis" (Van der Ploeg and Veugelers, 2008).

We focus our paper on the French system of university-industry technology transfer. This is an interesting case to investigate from the prospective of technical efficiency as the French system in the first phase of development. Two important actions have been undertaken from the French government. The July 1999 Innovation Law constitutes the main policy decision taken to favour technology transfer processes between universities and industry. Since its introduction, some efforts have been made but the general view is that there is still much room for improvement. In addition to the previous law, a law for public accounting was adopted in 2001 to introduce a 'new public-management oriented' reform. This reform defines for all public interventions (including research and higher education) a set of objectives, along with corresponding sets of indicators patent-based to mirror technology transfer activities of French university. Given that, it becomes important to analyze the performance of French technology transfer activities in its first phase of development taking into account the peculiarities of its new legislative framework to provide useful insights to university managers and policy makers. To be the more adherent as possible to the policy makers prospective, we adopt in the efficiency analysis the patent-based sets of indicators as metrics used in the production model of technology transfer.

Hence the main contribution of the paper is threefold:

(i) to provide the first quantitative assessment of French TTOs (in-)efficiency based on an original and detailed dataset, enriching the European empirical evidence on technology transfer;

(ii) to investigate the TTOs' inefficiency determinants by applying a recently developed statistical approach based on Data Envelopment Analysis and bootstrapping techniques (Simar and Wilson, 2007);

(iii) to discuss the policy implications of the results compared with existing studies on other countries.

The remainder of the paper is organized as follows. Section 2 presents a literature overview on TTOs efficiency; Section 3 examines the French context; Section 4 describes the methodology applied; Section 5 illustrates the data and formulates the production models. Section 6 is devoted to the investigations on the TTOs (in-)efficiency determinants. Section 7 reports the empirical findings. In the framework of the recent institutional policies, the final section discusses the main results comparing them with the existing literature and outlines further developments.

2. An overview on the literature

In general, the efficiency measurement of TTOs is a tricky issue. The complexity is due, on the one hand to the intangible nature of the production process that poses questions on how to measure results of this activity, and on the other hand to the complexity of the network between institutions and stakeholders, pursuing their own interests (Mowery and Oxley, 1995).

Nonetheless, the literature on efficiency of university technology transfer has expanded rapidly in recent times. Siegel et al. (2007) present excellent international surveys on the burgeoning literature on TTOs. In particular, this study describes the role of TTOs, documents the increasing rate of commercialization of intellectual property both in US and European universities, and addresses stakeholders and policy-makers challenges. Moreover, it reviews a selection of empirical studies on the performance of TTOs and highlights the differences in available empirical evidence between US and Europe, acknowledging a few papers based on European data which have appeared only recently. This might be owed to a less developed technology transfer activity in European universities (Siegel et al., 2008) as well as to the lack of micro data (e.g., Bonaccorsi and Daraio, 2007). Lastly, the survey indicates an increasing recognition that technology commercialization can occur through several modes. As a consequence, in the literature, policy issues related to technology transfer are examined under two perspectives: the traditional perspective looks at the licensing and patenting dimension of technology transfer, while the more recent one includes the creation of spin-off firms by academic scientists as additional channel of technology transfer.

We focus the overview on the strand of literature related to the traditional mode, in particular the patenting dimension of technology transfer because the 'new public-management oriented' reform, taken in 2001, introduced patent based indicators to monitor and foster technology transfer activities in France. This strand compasses several empirical studies on US university technology transfer (e.g. Thursby and Thursby (2002), Thursby and Kemp (2002), Siegel et al. (2003)), one study on the UK system (Chapple et al. 2005), and one on the Spanish system (Caldera and Debande, 2010). Recently, Siegel et al. (2008) offer a comparison of the relative performance of TTOs in UK and US. These studies, except Caldera and Debande, (2010), are based on production function framework and estimate the frontier, against which the efficiency (and productivity) is measured, using both Data Envelopment Analysis (DEA) and Stochastic Frontier Estimation (SFE). Since the seminal works of Thursby and Thursby (2002) and Thursby and Kemp (2002), academic research has been focused on the investigation of institutional, environmental and organizational factors, which possibly affect the relative performance of TTOs generating inefficiencies.

Based on a multi-input and multi-output DEA framework, Thursby and Thursby (2002) and Thursby and Kemp (2002) study the licensing activity of US TTOs and find that the growth in commercialization was led by a change of attitude of professors to patent rather than by shift in type of research (e.g.; from basic to applied). They show that high levels of inefficiency among TTOs might be explained by the degree of specialization in outputs unrelated to licensing activity rather than from competencies in licensing, the quality of research and the nature of faculty. When ownership enters as environmental variable in the regression, they find private university more likely efficient than public ones, as expected. This could be because private universities are able to specialize to greater extent than public universities, which have greater service commitments and teaching duties. Surprisingly, they find that universities with medical school are less likely to be efficient. This reduction in efficiency may be related to the heavy services commitments of medical school which might offset the efficiency advances stemmed by the fact that a large fraction of university licenses are in biomedical area and that medical schools are more engaged in late stage development of clinical trials.

By using a one-stage stochastic frontier estimation approach, Siegel et al. (2003) make a step further exploring several causes which might impact the inefficiency. Besides the presence of medical school and the legal status, they consider also the age of TTOs as proxy of the TTO experience. Among the three variables, only age has found having a positive and statistically significant impact, implying possible learning effect in university management of intellectual property. Moreover, they point out that the degree of industry R&D intensity and the GDP of the area where the TTO is located is crucial in the technology transfer process. For instance, it facilitates the university-industry relations and universities are more likely to license technology to firms located nearby. They find a positive association between the intensity of industrial R&D activity and TTO efficiency, implying spillovers effects. However, the authors conjecture that some of the variation in the relative TTOs performance might be also attributed to organizational practises (such as fund reward systems, compensation and staffing practices and so on.). Regarding this aspect, the authors provide only a qualitative analysis but subsequent studies (e.g., Link and Siegel (2005); Friedman and Silberman (2003); Lach and Schankerman (2004); Bercovitz *et al.* (2001), Belenzon and Schankerman (2007)) confirmed this intuition through quantitative analysis.

The first analysis on European TTOs is presented by Chapple et al. (2005) with the case of 50 UK TTOs for the year 2001. They compare DEA and SFE estimates and assume inefficiency depending on institutional and environmental factors. In line with previous studies, they find heterogeneity and poor-level in relative performance but, in contrast, they find decreasing returns to scale to licensing activity. Moreover, the authors find that both having a medical school and having longer experience (that is, being older) affect negatively the TTO efficiency, contrasting the evidence presented in Siegel (2003). The difference in the first result might be ascribed to differences between product markets for health care in UK and US. The second difference might be ascribed to the fact that, being UK TTOs age correlated to size, this result could reflect diseconomies of scale. Moreover, UK older universities may employ strategies of maximising licensing revenue, as opposed to new TTOs, which tend to maximise the number of licensees. Turning to regional R&D intensity and regional GDP, it appears that both have a positive effect on TTO efficiency. This could be because of agglomeration and spillovers effects from private R&D. More recently, three papers have appeared. The first one is proposed by Anderson *et al*. (2007) and provides US TTOs efficiency ranking based on DEA with weight restrictions. It confirms previous results on the variation of performance between TTOs in private and public universities and those with and without medical school. The second one, proposed by Siegel *et al.* (2008), constitutes the first analysis based on cross-country comparison. By estimating efficiency via the stochastic multiple output distance function, they find constant returns to scale, and possibly decreasing returns to scale, for TTOs in technology transferring. Moreover, they find US TTOs be more efficient than UK TTOs. In line with previous studies they find that older TTOs are less efficient, being older TTOs less focused on licensing but rather on alternative mechanism of technology transfer. On the other hand, in contrast with previous results, they find that universities with medical school are more efficient. They also consider the presence of science parks and incubators as other institutional factors that might explain variation in relative performance. They find that the presence of university science park does not impact on the TTOs efficiency while universities with incubator appear to be closer to the efficient frontier.

Lastly, Caldera and Debande (2010) propose a study on 51 Spanish universities in technology transfer over the period 2001-2005. They show that universities with well established policies and procedures for the management of technology transfer perform better. However, the performance of university is positively affected by the size and age of the relative TTO rather than TTO characteristics. In contrast with the study by Siegel et al. (2008), they find that universities with science parks perform better than those without.

Our paper contributes to the literature on the performance of TTOs in three directions.

Firstly, to the best of our knowledge, this is the first study that examines the French university system. Secondly, as described in Section 4, we use a recently developed methodology to investigate on the determinants of the performance heterogeneity across TTOs. Thirdly, we compare our results with existing studies on other countries and discuss the policy implications.

3. The French context

Over the last two decades, the French research system - in both its public and private dimensions - has undergone structural changes which led to the progressive disappearance of the dominant role of the Colbertian State (Mustar and Larédo, 2002). In fact, the French research system was based on a very specific interventionist model, characterized by four main features, which emphasised the dominant weight of large civil and defence programmes, the division between universities and the French national research council (CNRS); the congenital separation between research and firms and finally the concentration of public support on a few large companies. This model is undergoing fundamental changes since the 80's, giving way to a more complex system, where a relative reduction of the resources devoted to public research, the increase of the institutional complexity and the need to serve a "third mission" of contributing to the local economic development (Etzkowitz, 2002) are the main challenges that need urgently to be faced.

The French research system is largely public: all universities, most of the other Higher Education Institutions –HEIs- (except some business schools) and the large research organizations (PROs) are public, an high share of research-related resources of HEIs and PROs comes from public sources compared to other sources (contracts with firms or not-for-profit organisations, donations, Intellectual Property Rights -IPR- revenues, etc), and all teachers-researchers and a very high share of researchers in universities and PROs are civil servants.

The French research system is composed by 88 universities active in higher education teaching and (at different level) in research activities; several dozens of HEIs, including most "Grand Ecoles" in engineering and public administration; and around 25 PROs . Heterogeneity also notably lies in size and discipline coverage. We do not cover the PROs, some mainly oriented towards fundamental research, (such as CNRS, INSERM, INRA and so on), other mainly oriented towards applied research and commercialization (such as CEA, CNES, ADEME and so on)[1].

We will concentrate our analysis on the main universities under the supervision of the Ministery of Education, Higher Education and Research (MENESR)[2].

A key aspect of the reserach system is its "duality" , in which large PROs stand beside universities[3]. Although the frontiers tend to be increasingly blurred, this breakdown still has a very strong influence on research activities, governance, allocation of resources, and so on. Indeed, 44% of the approximatively 3,000 university research units (including all of the top ones) are "mixed research units" between PROs organized at national level (especially CNRS and INSERM) and individual universities organized at local level (those "mixed research unit" sometimes involve more than one university and more than one PRO). A mixed research unit, according to local agreements, can follow the procedures and the organisational setting of one of the institutions[4] supervising the research unit. Of course, this "duality" induces some contraints and structural bias on the data

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[1] But the creation in 2005/06 of two agencies (ANR – National Agency for Research, and AII – Agency for Industrial Innovation, more on the industrial research side) may tend to re-centralize a large share of the funding role of more classic agencies, at least with regard to the project-based funding.

[2] In addition, on the upstream end of the research spectrum there are very few big foundations, which mainly are in medicine (such as Institut Curie and Institut Pasteur). At the downstream end of the research spectrum a large number of Technical Centers (sector oriented) and Technologies Resources Centers (often regionally based) co-exist.

[3] Another duality resides on the HE side, where universities stand beside the so-called Grandes Ecoles.

[4] Even if various common rules and procedures, forms of coordination and mutualization processes have recently been fostered.

collection and on the database used in the analysis[5]. This specificity of the French HEI system may have an influence on the technology transfer activities and therefore should be taken into account.

The French government has developed an explicit policy to deal with the supposed weakness and difficulties of the research system. It did implement new policy tools and reforms, most of them aiming to promote public research-industry interactions. The July 1999 Innovation Law was the main decision taken to develop a general framework favouring technology transfers between universities and industrial sectors. The Innovation Law imposes to all universities to develop an explicit policy for 'commercialising' their results. The legal frame has been adjusted in order to allow for the creation of 'Services d'Activités Industrielles et Commerciales: SAIC' ("Department for industrial and commercial activities"), in other words for the creation of TTOs. In fact some of the private accounting rules were introduced for those activities, even if the TTOs are not independent legal entities.

For the academic researcher, the Innovation Law implements an incentive system to become more entrepreneurial and, *vice versa*, for the existing firms to increase their scientific expertise. In particular, it was intended to encourage: (i) the creation of new firms; (ii) an increase in the number of technological innovation and research networks; (iii) financial and legal reforms to benefit innovative companies.

In addition, and in parallel, in 2001 a law for Public Accounting (Loi Organique sur la Loi de Finance, LOLF hereafter) has been adopted. This is a "New Public Management oriented" reform that affects all state expenditures, in a framework of re-organisation of the public intervention into broad missions, broken down into programmes, and finally into actions. A set of objectives, with corresponding sets of indicators are assigned to all public interventions. University and PRO activities are aligned with the mission "Research and Higher Education". To monitor the foster of

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[5] For a deeper discussion on this issue, see Bach and Llerena (2007).

science-industry relations, the indicators used for university research activities that refer to technology transfer activities are mainly based on patents (Assemblée Nationale, 2005).

Therefore, the pressure for developing technology transfer indicators and corresponding statistics came from the govermental authorities in order to monitor the efficiency of public spending, in particular in science and techonology. As a matter of fact, at least during the period under consideration in our paper (2003-2007) the main indicators of technology transfer have been based on patents applications in a broad sense, including extentions, and similar IPR instruments for software. For this reason, in the empirical setting of our analysis we use as proxy of the outputs the patent related measures. Our paper, in fact, provides the first assessment of the (in-)efficiency levels of the TTOs in France, after this explicit policy to develop these patent related indicators in the early 2000s. Moreover it investigates the factors behind the inefficiency differentials and contributes to fill the gap existing in the literature, related to the lack of empirical evidence on the French system of university TTOs.

4. The methodology: A two stage semi-parametric bootstrap based approach

We examine the determinants of (in-) efficiency by using a two-stage DEA estimation based on the bootstrap procedure proposed by Simar and Wilson (2007), wherein technical (in-)efficiency is estimated in the first stage and then regressed on a set of external (environmental) factors in the second stage.

Beside the major advantages related to DEA estimation, that is the lack of any assumption on the functional form of the production frontier and the simultaneous use of multiple inputs and outputs, the bootstrap procedure overcomes some of the main issues related to the traditional two-stage DEA analysis (also acknowledged by Chapple *et al.* (2005)) by allowing for (i) the bias correction incorporated in DEA due to the uncertainty associated to sampling variation, particularly evident in the case of small sample size, as in our analysis (ii) accounting for the serial correlation structure of

DEA efficiency scores when the regression of these scores is estimated on the environmental variables at the second stage.

We assume that TTOs share the same production frontier[6], which respects standard regularity conditions. Let each TTO activity be described by a set of inputs (resources) $x_k \in \Re_+^H$ which are converted into a set of outputs $y_k \in \Re_+^M$ via an underlying production technology. It can be characterized by the technology set, defined as:

$$\Psi = \{(x, y) \in \Re_+^H \times \Re_+^M \mid x \; can \; produce \; y \; \} \tag{1}$$

Since the real technology is unknown, its estimation is required. Thus, at the first stage, we first estimate (1) via DEA, as follows:

$$\hat{\Psi}_{DEA} = \Big\{(x, y) \in \Re_+^H \times \Re_+^M \mid \sum_{k}^{N} z_k y_k^m \geq y^m, m = 1, \ldots, M$$

$$\sum_{k=1}^{N} z_k x_k^h \leq x^h \; h = 1, \ldots, H \; for \; (z_1, \ldots, z_N), \; such \; that \sum_{k=1}^{N} z_k = 1; \; z_k \geq 0 \quad k = 1, \ldots, N \Big\} \tag{2}$$

where $z_k \geq 0$ are the intensity variables over which the maximization is made. The estimation of the technology frontier makes efficiency measurement possible. Various measures of efficiency are possible. We use the Debreu (1951)-Farrell (1957) measure of (in-)efficiency as radial distances to the estimated frontier. In the paper we adopt an output oriented framework: given the level of resources (inputs) used by university TTOs, they look at the maximization of their outputs. Then the Farrell output oriented measure of technical (in-)efficiency score is given by:

$$\hat{\lambda}(x, y) = \max\left\{\lambda \,\middle|\, (x, \lambda y) \in \hat{\Psi}_{DEA}\right\} \tag{3}$$

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[6] This assumption allows us to compare efficiency across TTOs.

In this approach, a TTO is considered efficient if it lies on the "efficient" estimated frontier, i.e. if $\hat{\lambda}\,(x_k, y_k) = 1$, otherwise it is inefficient and $\hat{\lambda}\,(x_k, y_k) \succ 1$. $\hat{\lambda}\,(x_k, y_k)$ measures the proportional increase of outputs that a TTO could realize using the same level of inputs it is actually using. The main limitations of DEA are its deterministic nature (all the distance from the efficient frontier is assumed to be inefficiency) and its biased estimation. Hence we control for the uncertainty of DEA scores estimating their bias and confidence intervals by using a consistent bootstrap approximation of the efficiency distribution (see for more details Simar and Wilson, 2000).

At the second stage, we analyze the dependency of the efficiency specific to each TTO on a set of environmental factors, Z_k. We follow Simar and Wilson (2007) by applying: (i) a truncated regression to consistently estimate the parameters by using maximum likelihood and (ii) a consistent bootstrap for inference in the case of truncated regression.

The bias corrected efficiency scores, resulting from the first stage, enter the regression as dependent variable in the second stage. As efficiency scores are bounded at unity, the distribution of the error term is restricted. Formally, the model is defined as follows:

$$\hat{\lambda}_k^c \approx Z_k \beta + \varepsilon_k \quad \forall k = 1, \ldots, N \tag{4}$$

where $\varepsilon_k \sim N(0, \sigma_\varepsilon^2)$ such that $\varepsilon_k \geq 1 - Z_k \beta, \quad \forall k = 1, \ldots, N$, being the dependent variables bounded by unity. The estimation procedure and the bootstrap algorithms are described in more details in Simar and Wilson (2007).

5. Data and production models

Data from French TTOs were collected by B.E.T.A. (Bureau d'Economie Théorique et Appliquée, UMR UdS-CNRS 7522, Strasbourg) in 2005, 2007 and 2009[7], during regular surveys,

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[7] See Bach and Llerena (2006, 2008, 2010).

funded by the French Ministry in charge of Higher Education and Research. The surveys had the institutional support of CURIE (the French association of TTO managers), CPU (the Conference of University Rectors) and CDEFI (Association of Engineering Schools Directors). The surveys adapted to the French context the model used by the Association of University Technology Managers (AUTM) in the US. The purpose of the surveys was to build a comprehensive database, focused on variables characterising different dimensions of technology transfer by Higher Education Institutions such as Universities and Engineering Schools (generically called "universities" thereafter). A first questionnaire was elaborated in 2004 and e-mailed to 74 universities. In 2007, it was improved in both qualitative and quantitative aspects and submitted to a larger number of universities (96 universities). More recently, the survey, on line, allowed further refinements of the questions and a more efficient process of data collection.

As proxies of the outputs of the technology transfer process, the survey provides us with the following output variables: Patent Applications (PAT_APP), Software Applications (SW_APP), Number of Patents with submitted extension requests (PAT_EXT), number of extensions required (Nb_PAT_EXT). This set of indicators is the one build and used by LOLF to measure the French university performance in technology transfer activities. In particular, the first two metrics constitute the "core" outputs of the technology transfer process while the third and forth constitute ancillary outputs. We deliberately use this set of output metrics because this is consistent with the official metrics used by LOLF. As input measures, the survey provides us with two metrics: labour measured by the number of full time equivalent employees in the TTO (ETP) and the number of publications (fractional) (PUB)[8]. The latter is a proxy for the scientific stock produced by the university and for the potential knowledge to be transferred. Although several universities reported numerous zeros, we end up having a database comprehensive enough to carry out an efficiency assessment: 51 TTOs and time span from 2003 to 2007.

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[8] Elaborated by OST using the ISI publications data.

Time lags might occur between the inputs used and the outputs produced, causing a mismatch in the production process. For instance, inputs used today will produce outputs in the coming years., In order to prevent any error from time lags, we base our analysis on 5-year averages of the data, as in previous studies (e.g.; Thursby and Kemp, 2002; Anderson *et al*., 2007). We end up with a balanced panel of 51 TTOs, classified by category of disciplinary field of the related university (i) Polyvalent University with Medical School (UPAM), (ii) Polyvalent University without Medical School (UPSM), (iii) Polytechnics (INP), (iv) Science Universities (USC), (v) Social and Human Science University, Law and Economics (USH/D-E), (vi) Engineering School (ING).

Summary statistics are reported by categories in Table 1. Two particularly noteworthy features emerge related to the issues of input usage and output produced. On the one hand, there is substantial TTOs heterogeneity within each category, as indicated by the high standard deviations. On the other hand, some categories exhibit a certain degree of output diversification.

Not surprisingly, Science Universities exhibit higher values in the input and output statistics (mean, median and standard deviation) compared to TTOs related to USH/D-E. These considerations lead us to expect substantial evidence of inefficiency, which might stem simply from other factors (such as university category, intrinsic characteristics of TTOs, and regional influences) rather than from competencies in technology transferring. We, therefore, support the hypothesis that there may be different ways to approach the technical efficient frontier.

[TABLE 1 AROUND HERE]

From Table 1, it could be stemmed the importance of accounting for both the core (patent and software applications) and the ancillary outputs (extended output portfolio with the number of patents whose extension is submitted and the number of extensions), as the volume of the latter could not be disregarded.

[TABLE 2 AROUND HERE]

However, by inspecting Table 2, we find high levels of correlation (higher than 87%) between PAT_APP and both PAT_EXT and Nb_PAT_EXT. We, therefore, model the production process according to two inputs-outputs configurations: one wherein we select as outputs patent and software applications (Model 1) and another one wherein patents whose extension is submitted and extensions of patents are also included. Model 2 aims to capture the entire dimension of technology transfer whereas Model 1 captures only the core activities. From a statistical point of view, however, the two models will produce similar estimates due to the correlation among variables but Model 2, being estimated on a higher dimensional space (more inputs and outputs), will be certainly affected by the curse of dimensionality. This implies lower level of statistical precision as well as lower discriminatory power among DEA estimates. Therefore, we restrict the second stage to the analysis of Model 1.

6. Determinants of Efficiency

Specific University-TTO characteristics

This set of variables encompasses the most commonly used institutional characteristics, namely: TTO age, university size, presence of an university-related hospital. We do not control for the ownership (private vs. public) because all French TTOs are related to public universities.

- Age (AGE). This is the length of time that has passed since technology transfer appeared as a specific function in the university and represents a proxy of TTOs experience. In fact, the university might obtain some advantages from "learning by doing" effects; for instance the creation of a profitable portfolio of qualitative research results (Friedman and Silberman, 2003) or higher quality in the management of university intellectual property. However, previous studies produced contradictory results. Friedman and Silberman (2003) and Lach and Schankerman (2004) find that older TTOs execute more licenses, suggesting that efficiency gains arise as TTOs gain experience in the management of university technology transfer. In contrast, Siegel et al. (2009) find that older TTOs are less efficient and Caldera and Debande (2010) find that TTO experience only affects R&D contract activity and not the other dimensions of technology transfer. As a result, the impact of this variable is uncertain.

- Number of Professors (SIZE). This is used to proxy the size of the university related to the TTO as larger universities are expected to produce more research. For instance, Caldera and Debande (2010) find that the number of professors working at the university has a significant positive impact on TTO efficiency (when the output is measured in terms of R&D contract income and number of contracts). We expect a positive impact of this variable.
- University-related hospital (HOSPITAL). In France there are USC universities with both medical schools and an university-related hospital while UPAM universities may have only the medical school. We consider therefore that it is more informative in the French case to control for the presence of an university-related hospital (dummy variable equal to 1 if there is an university-related hospital and 0 otherwise). The presence of an university-related hospital is a guarantee of an ongoing significant medical research, whereas a simple medical school reveals only a training activity. It is usual thought that medical research is an important source of technology transfer. However, in the literature, the results are controversial. Siegel et al. (2008) find that universities with medical school are more efficient while Thursby and Kemp (2002) and Chapple et al. (2005), among others, find the opposite results.
- University disciplinary category dummy variable. We use one dummy variable for each TTO according to the university disciplinary category it belongs to (ING, UPAM, UPSM, USC, and USHS) to capture any possible effects due to specific, managerial and organizational features of each university disciplinary category.

[TABLE 3 AROUND HERE]

Table 3 shows a descriptive analysis on the variables AGE, SIZE and HOSPITAL.

By inspecting Table 3, it appears that science universities (USC) are the most experienced (mean: 15,215 years). The average shows that it is well beyond the 'Innovation law' in 1999 which made the existence of an explicit technology transfer policy at the university level compulsory. It is also the case for the category ING (engineering schools) and UPAM (i.e. universities with medical schools).

Regional characteristics

This set of variables encompasses both the economic and R&D intensity characteristics of the region where the TTO is located. France is characterized by high differentials in territorial dynamics and regional policies for research and innovations (OST, 2010). Previous studies find that these factors might drive the performance of TTOs. For instance, a region with higher economic performance is likely (directly or indirectly) to enhance the technology transfer process. Likewise, it is also the case for a region where investments in R&D activities are higher than others (e.g., Siegel *et al.* 2008, Chapple *et al.,* 2008). As previous studies, we use an index of GDP per capita.

However, we also distinguish the regional intensity in R&D into public and private R&D intensity. We expect to be able to distinguish between inside pushing dynamics (public expenditures) and outside pulling one (private R&D). In particular Regional R&D intensity is proxied by R&D expenditure per capita, the R&D being either public or private.

In addition, we analyse the impact of the growth of the economic and R&D intensity on the performance of TTOs. Because we analyzed average-efficiency over the period 2003.-2007, we derive the relative growth rate, expressed in percentage over the all period analyzed. They are:

- Growth Regional GDP intensity which is the growth rate of GDP per capita;
- Growth Public R&D intensity which is the growth rate of public investment in R&D;
- Growth Private R&D intensity is, finally, the growth rate of private investment in R&D.

7. Empirical Results

We first discuss the heterogeneity of performance across TTOs and then the main determinants of the efficiency scores.

7.1. (in-)Efficiency scores of the TTOs, by category of universities

Before starting the DEA frontier estimation, one might wonder which returns to scale are exhibited by the technological frontier: either constant (CRS) or variable (VRS). Previous papers based on SFE analysis (e.g.; Siegel *et al.*, 2003 Chapple *et al.*, 2005, Siegel *et al.*, 2008) show that TTOs are more likely to work at constant or decreasing returns to scale. Papers based on DEA analysis, on the other hand, assume *a priori* variable returns to scale (e.g. Thursby and Kemp, 2002; Anderson *et al.*, 2007), allowing for any scale effects. However, a wrong characterization of the production frontier might lead to incorrect estimates. We therefore investigate the type of returns to scale by using a statistical test based on the bootstrap (see Simar and Wilson (2002) for further details), where the average of the ratio between the efficiency measures under CRS and a VRS technology is taken as statistics. We reject the null hypothesis of CRS at 5% confidence level for both models (p-values equal to 0.0440 for Model 1 and p-value equal to 0.0405 for Model 2), accepting global VRS for French TTOs.

We report the geometric average of the (bias-corrected) efficiency by categories of TTOs and of the whole sample, along with the individual TTO efficiency scores (see Tables 4 and 5). Efficiency scores are reported à la Farrell (1957): a TTO is efficient if the score is equal to unity and inefficient if greater. In order to compare our results with previous results, it is useful to express the efficiency scores à la Shephard (1970), that are the reciprocal of the Farrell efficiency scores and represent the *relative %-level* of efficiency. We discuss the results by considering the bias-corrected efficiency scores. For the sake of completeness, we report also the DEA biased efficiency scores, and some statistics derived from the bootstrap procedure.

[TABLE 4 AROUND HERE]

[TABLE 5 AROUND HERE]

From the analysis of these tables, it can be noticed the substantial level of inefficiency in our sample. Under model 1 (i.e. with only the core outputs), the results show that the overall average Farrell-efficiency (or % efficiency) score is 2.202 (49.5%), suggesting that the representative French TTOs could double the technology outputs given the same amount of inputs used. As expected, similar results are found when multiple outputs are included (under model 2). In fact, the average Farrell-efficiency (or % efficiency) is 1.961 (or 51%). Overall, we find low level of efficiency in both models based on two-outputs and four-outputs, respectively. These findings are partially consistent with previous results. In fact, they are in line with UK findings (Chapple *et al.*, 2005), which were based on a single output (either number of licenses or licensing income). However, they differ from results based on joint analysis of US and UK TTOs (Siegel *et al. ,*2008), where the average efficiency is set at 70.7% and the results on US TTOs (Thursby and Kemp, 2002), based on a multi-output model, where the average efficiency is set at 82%. Of course, the comparison of our results with previous studies is only to give a first rough descriptive picture of the phenomena, and have to be taken with care because the size of the samples analysed, the methods applied to estimate the efficiency scores, the variables used in the analysis, and so on, strongly differ from one study to the others.

When we analyze the efficiency by category, we find some categories performing better than others. The best performers seem to be the science university (USC) and the Engineering School (ING) TTOs, followed by the Polyvalent university with medical school (UPAM) TTOs .On the contrary, the typical Polyvalent university without medical school (UPSM) TTO and the Social and Human Science University, Law and Economics (USHS/D-E) TTO rank at the bottom. Under model 2, the ranking is slightly different: the more efficient is the Engineering School (ING) TTO, followed by the science university (USC) TTO and the Polyvalent university with medical school (UPAM)

TTO. The Social and Human Science University, Law and Economics (USHS/D-E) TTO with the Polyvalent university without medical school (UPSM) TTO rank at the bottom. These findings suggest heterogeneity in performance intra-category and support the hypothesis that for some categories of universities (including disciplines such as biological science and engineering) technology transfer is more important than for other categories. We will take into account this association in the next section where we investigate on the determinants of inefficiency.

When we analyze the performance within each category, we also find evidence of efficiency variation (see the boxplots depicted in Figure 1). For example, in model 1, for UPSM TTOs efficiency scores vary from 1.249 to 4.677; or for USC TTOs efficiency scores vary from 1.271 to 4.645 if bias-corrected. In model 2, the variation is even larger. For UPSM, e.g. it varies from 1.322 to 10.543. However, despite internal disparities, the best performers for each category obtain similar efficiency scores, especially if we exclude the particular case of USHS/DE. In model 1, the range goes from 1.25 (UPAM) to 1.28 (UPSM) and in model 2 from 1.26 (UPAM) to 1.32 (UPSM).

[FIGURE 1 AROUND HERE]

These findings of “internal” disparities within disciplinary categories favour the hypothesis that not only intrinsic characteristics of each category might affect TTOs performance, but also additional external and general factors might strongly contribute. These factors, as also found in Thursby and Kemp (2002), might be related to university specialization (basic research vs. teaching) to other outputs unrelated to technology transfer activities rather than to specific competences. Consequently, empirical evidence requires careful interpretation when conclusions are drawn relying upon aggregated point estimates of efficiency both at category and system level on this respect, the analysis of confidence intervals reveals interesting aspects. In fact, they highlight that the difference in efficiency across TTOs within the same category are not as remarkable as the DEA point estimates show (their confidence intervals, in fact, overlap). This suggests a certain degree of homogeneity in performance, although clear dissimilarities are still present. Overall, for each category it is possible to identify 2 to 3 sub-categories of TTOs equally efficient. Thus, we can conclude that exist some heterogeneity intra-category, justifying a specific treatment of the determinants of efficiency by category of university.

Lastly, the boxplots in Figure 1 disclose information about the presence of possible outliers in our sample. As DEA is deterministic, the presence of outliers might be a source of distortion in the estimation. Other studies, such as Chapple *et al.* (2005) eliminate these extreme observations to mitigate their influence on the efficiency estimates. However, in this paper to avoid the exclusion of some important TTOs from the analysis, we prefer to keep all the observations in the sample.[9]

7.2 The determinants of the (in-)efficiency

Table 6 presents results from the empirical analysis on the determinants of technical efficiency. Since we express DEA scores à la Farrell that are equal to one if the TTO is efficient and higher than one if it is inefficient, i.e. the higher the score the more inefficient is the TTO, the parameters with negative sign indicate sources of efficiency (i.e. have a positive effect on the efficiency level). We report the estimates and the relative confidence intervals (at 90%, 95% and 99% probability). Results reveal that the university TTO age appears to have a positive effect on efficiency in technology transfer. There is a learning process which takes place allowing an increased professionalization of the TTO staff members. This finding is in line with Mowery *et al.* (2001), Siegel *et al.* (2003) but in contrast with Chapple *et al.* (2005), Siegel *et al.* (2008) for US and UK TTOs, and partially with Caldera and Debande (2010). It indicates that the different strategies followed by TTOs in different countries did certainly matter (degree of specialisation, incentives, etc…). In contrast, the university SIZE contributes largely to the TTO efficiency. This result suggests that universities with more researchers are likely to be more active in the technology transfer. Measured by the personal, the size indicates the potential transferable knowledge in terms

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[9] In follow up investigations we plan to analyse the efficiency of French TTOs by using recently introduced robust (to outliers) methods. See the final section of this paper for more details.

of possible patentable results. This confirms the results obtained by Caldera and Debande (2010). Having a medical school within a hospital is an important source of inefficiency for the TTO. It confirms partially results of previous studies (e.g. Thursby and Kemp, 2002; Chapple *et al.*, 2005), while contrasting the findings in Siegel *et al.* (2003) and Siegel *et al.* (2008). This effect is certainly due to the competition between two institutions. Both institutions, the University and the University-related hospital, are legally independent entities. As a consequence, they both try to capture the potential technology transfers from life and medical sciences. However, in our database, our measures are then partial; only the university side is counted.

As far as the regional effects are concerned, there is a direct connection between R&D activity and TTO efficiency. Both Public and Private R&D Expenditure are found to have a positive impact on efficiency, with Private R&D Expenditure having the larger impact. This implies that the interaction between private firms and TTOs enhances the performance of the latter. This result is partially confirmed by the impact of growth rate term as only the Private R&D expenditure results to be the driver of performance. It means that the dynamics of technology transfer is essentially pulled from the 'outside'. This is in line with Siegel *et al.* (2003), Chapple *et al.* (2005), Siegel *et al*. (2008). On the contrary, while previous paper found the economic performance at regional level not significant (Siegel *et al.*, 2003, Siegel *et al.* 2008), we find that there is a negative relation between the economic performance of the region where the TTO is located and the TTO itself.

The dummy variable on university disciplinary category highlights that some categories of universities, namely ING and USC have some specific internal features which positively affect the TTOs performances. This result confirms a classical wisdom about the technology transfer potential of medical sciences and engineering compared to other fields of research. It is also in line with findings in Siegel *et al.* (2008) and Caldera and Debande (2010).

[TABLE 6 AROUND HERE]

8. . Conclusions

This paper analyses for the first time the efficiency of the technology transfer operated by the French university system and its determinants.

By analysing an original and detailed dataset built by the BETA (University of Strasbourg) for the period 2003-2007, we were able to assess the (bias-corrected) DEA efficiency scores of 51 French TTOs categorized by type of universities. As input and output measures, we use the performance indicators implemented and used by the policy makers. The results show substantial inefficiency across French TTOs as the average TTO experiences a level of inefficiency of around 2, meaning that it could double the production of its outputs (in terms of patents applications, software applications, number of patents whose extension is submitted, number of extensions required), given the level of resources (inputs) it is using. However, this result should be carefully interpreted as we also found that the efficiency varies according to the disciplinary field associated to the TTOs, implying that the inefficiency stems from disciplines less related to patent activities. This is confirmed by the fact that universities focused on science natural and engineering are more efficient in the technology transfer. This result is not surprising because, as illustrated above, our output indicators are mainly based on patenting activities, as imposed by the policy makers.

In addition when we analyse the inefficiency distributions, we found efficiency variation also within each category of TTOs, including the science and engineering. We have variance intra- as well as inter-categories. This result indicates that the indicators of performance used (patents and similar IPR outputs) does not represent the full range of TTOs activities. Commercialization via patents and licenses is a particular way for public research institutions to contribute to the economy. But there are many other ways to collaborate and to transfer knowledge. The interactions are formal activities such as contract research, public-private partnerships, collaborative research, service deliveries, consultancies, but also informal such as advices and networking, expertises and cultural activities (Perksman *et al,* 2011, for a detailed survey). Most of the formal interactions, such as patents related activities, are usually handled at least partially by TTOs, and represent in many cases a great part of their activity.

The existence of the important variations in and between categories implies an important consequence for policy makers: Technology transfer policies have to be fine tuned and not governed by any idea of "one unique best practice model" (intra-category variations), driven with narrowly defined performance indicators (intra and inter-category variations). The most important is the necessity of an appropriate specification of the organisation of the technology transfer according to the specificities of the university and its environment.

The analysis of the determinants of TTOs efficiency confirmed that some categories of universities, namely universities in engineering, natural science and polyvalent with medical school have some specific internal features which affect statistically their TTOs performances. Further, the analysis confirms that the outcome of multiple affiliations such as between medical school and a hospital is an increased inefficiency, as shown in previous studies for the US and UK. Regarding the institutional characteristics analyzed, we found that seniority of TTO and its size have positive effects on efficiency. Regarding the environmental factors, both Public and Private R&D Expenditure are found to have a positive impact on efficiency; however, in terms of growth rate, only Private R&D expenditure is the main driver of performance.

Overall, the important impact of seniority of the TTOs (particularly when the technology transfer function were introduced before 1999) and of regional characteristics might imply that the 1999 Law on Innovation had probably little impact on the efficiency of French universities in terms of Technology Transfer[10] measured by patents and related outputs.

Further investigations will be directed to include in the analysis more recent years, additional outputs to proxy also the informal channels of technology transfer and to take into account the

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[10] See Della Malva et al. (forthcoming) for confirmation, using other data and methods.

influence of outliers by applying the recently developed nonparametric conditional methodology (Daraio and Simar, 2007; Daraio, Simar and Wilson, 2010; Badin, Daraio and Simar, 2011).

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Tables of the paper

Table 1: Descriptive Statistics by categories

Class	*Variable*	*ETP*	*PUB*	*PAT_APP*	*SW_APP*	*PAT_EXT*	*Nb_PAT_EXT*
ING	Mean	6.197	661.105	3.629	1.303	0.810	2.667
	Median	2.500	737.461	3.000	0.000	0.000	1.000
	St.Dev.	6.496	398.331	3.734	2.801	1.504	3.851
	Min	0.500	52.741	0.000	0.000	0.000	0.000
	Max	26.650	1463.830	15.000	15.000	5.000	16.000
UPAM	Mean	5.173	783.978	4.083	0.820	1.868	1.974
	Median	4.000	723.696	3.000	0.000	1.000	1.000
	St.Dev.	4.709	354.676	3.665	1.385	2.133	2.194
	Min	1.500	0.000	0.000	0.000	0.000	0.000
	Max	26.650	1701.007	19.000	6.000	8.000	9.000
UPSM	Mean	2.639	357.671	1.474	0.345	0.436	0.718
	Median	2.000	224.847	1.000	0.000	0.000	0.000
	St.Dev.	1.686	319.849	2.458	0.965	1.334	1.555
	Min	0.000	51.567	0.000	0.000	0.000	0.000
	Max	7.000	1405.848	12.000	6.000	7.000	7.000
USC	Mean	11.662	2757.143	10.000	1.869	5.714	6.452
	Median	9.700	2511.680	8.000	1.000	4.000	6.500
	St.Dev.	8.670	1779.189	8.118	2.802	5.518	5.388
	Min	2.000	88.733	0.000	0.000	0.000	0.000
	Max	39.000	7664.471	40.000	12.000	18.000	18.000
USHS/D-E	Mean	3.180	45.779	0.150	0.600	0.083	0.083
	Median	2.000	30.146	0.000	0.000	0.000	0.000
	St.Dev.	2.997	48.016	0.489	0.883	0.289	0.289
	Min	1.000	1.000	0.000	0.000	0.000	0.000
	Max	11.000	140.983	2.000	3.000	1.000	1.000

Source: Authors calculations

Table 2: Correlation coefficients

	ETP	PUB	PAT _APP	SW_APP	PAT_EXT	Nb_PAT_EXT
ETP	1					
PUB	0.7833	1				
PAT _APP	0.7541	0.8321	1			
SW_APP	0.374	0.2841	0.466	1		
PAT_EXT	0.6258	0.733	0.8787	0.3966	1	
Nb_PAT_EXT	0.6747	0.7479	0.88	0.3709	0.9292	1

Source: Authors calculations

Table 3: Descriptive Statistics by categories of universities

Class	*Variable*	*AGE*	*SIZE*	*HOSPITAL*
ING	Mean	11.743	988.171	0.000
	Median	9.000	1072.000	0.000
	St.Dev.	9.160	465.108	0.000
	Min	0.000	436.000	0.000
	Max	28.000	1768.000	0.000
UPAM	Mean	7.923	923.692	0.923
	Median	8.000	850.000	1.000
	St.Dev.	3.124	619.429	0.277
	Min	2.000	410.000	0.000
	Max	14.000	2878.000	1.000
UPSM	Mean	4.569	1229.725	0.000
	Median	4.000	922.000	0.000
	St.Dev.	2.727	759.309	0.000
	Min	0.000	102.000	0.000
	Max	11.000	2700.000	0.000
USC	Mean	15.214	1181.500	0.750
	Median	16.000	1095.000	1.000
	St.Dev.	8.437	640.715	0.500
	Min	0.000	281.000	0.000
	Max	37.000	2286.000	1.000
USHS/D-E	Mean	4.250	1389.400	0.000
	Median	3.500	1470.000	0.000
	St.Dev.	3.193	489.197	0.000
	Min	0.000	624.000	0.000
	Max	11.000	1980.000	0.000

Sources: Age: Bach and Llerena 2006-2008-2010; Size: Aquameth-PRIME NoE database, all other variables: OST, 2008 and 2010.

Table 4: **Efficiency Estimates by university category, Model 1.**

University Type	Efficiency Estimate (EFF)	Efficiency Estimate Bias-corrected (C-EFF)	Estimated bias (Est-Bias)	Estimated Std (Est-Std)	Confidence Interval: lower bound (LB)	Confidence Interval: upper bound (UB)
ING-9	1.099	1.271	-0.172	0.074	1.118	1.408
ING-30	1.000	1.317	-0.317	0.129	1.037	1.531
ING-3	1.000	1.325	-0.325	0.130	1.034	1.531
ING-24	1.224	1.515	-0.291	0.116	1.270	1.719
ING-35	1.416	1.587	-0.171	0.085	1.442	1.762
ING-36	1.734	2.104	-0.370	0.157	1.789	2.400
ING-32	7.036	8.023	-0.987	0.476	7.138	8.975
Geom. Mean	1.567	1.902				
Std.Dev.	2.204	2.474				
UPAM-14	1.000	1.249	-0.249	0.086	1.036	1.385
UPAM-23	1.000	1.309	-0.309	0.119	1.031	1.486
UPAM-31	1.086	1.345	-0.259	0.121	1.122	1.571
UPAM-22	1.112	1.365	-0.253	0.116	1.145	1.580
UPAM-21	1.426	1.763	-0.338	0.151	1.478	2.041
UPAM-50	1.592	1.867	-0.275	0.113	1.633	2.078
UPAM-55	2.018	2.328	-0.310	0.136	2.069	2.594
UPAM-18	2.049	2.454	-0.405	0.167	2.121	2.771
UPAM-2	2.056	2.585	-0.529	0.230	2.115	3.016
UPAM-41	2.145	2.611	-0.466	0.217	2.199	3.029
UPAM-7	2.356	2.622	-0.267	0.148	2.378	2.935
UPAM-71	2.607	2.883	-0.276	0.157	2.637	3.222
UPAM-59	3.742	4.677	-0.935	0.436	3.875	5.460
Geom. Mean	1.719	2.078				
Std.Dev.	0.787	0.939				
UPSM-25	1.000	1.280	-0.280	0.121	1.033	1.492
UPSM-4	1.000	1.384	-0.384	0.172	1.030	1.651
UPSM-49	1.000	1.444	-0.444	0.235	1.029	1.867
UPSM-10	1.255	1.579	-0.325	0.155	1.289	1.866
UPSM-43	1.453	1.700	-0.247	0.107	1.488	1.913
UPSM-12	1.643	2.044	-0.401	0.156	1.702	2.311
UPSM-61	2.026	2.248	-0.223	0.119	2.056	2.505
UPSM-1	2.193	2.615	-0.422	0.219	2.252	3.062
UPSM-17	2.702	3.346	-0.644	0.292	2.794	3.870
UPSM-62	4.549	5.721	-1.172	0.515	4.689	6.721
UPSM-52	5.619	6.461	-0.842	0.386	5.724	7.239
UPSM-38	6.369	7.662	-1.292	0.498	6.567	8.627
UPSM-74	8.225	10.737	-2.512	1.428	8.412	13.401
Geom. Mean	2.292	2.856				
Std.Dev.	2.396	2.998				

University Type	Efficiency Estimate (EFF)	Efficiency Estimate Bias-corrected (C-EFF)	Estimated bias (Est-Bias)	Estimated Std (Est-Std)	Confidence Interval: lower bound (LB)	Confidence Interval: upper bound (UB)
USC-68	1.000	1.271	-0.271	0.121	1.033	1.498
USC-73	1.000	1.320	-0.320	0.126	1.034	1.530
USC-69	1.000	1.320	-0.320	0.138	1.038	1.563
USC-34	1.000	1.328	-0.328	0.149	1.028	1.591
USC-5	1.000	1.349	-0.349	0.143	1.022	1.565
USC-64	1.000	1.373	-0.373	0.162	1.034	1.626
USC-51	1.211	1.392	-0.181	0.076	1.250	1.544
USC-33	1.306	1.543	-0.238	0.101	1.344	1.748
USC-42	1.627	1.940	-0.313	0.151	1.683	2.235
USC-26	1.582	1.942	-0.361	0.156	1.636	2.249
USC-37	1.893	2.300	-0.407	0.183	1.947	2.647
USC-65	2.490	3.001	-0.512	0.224	2.562	3.437
USC-54	3.444	4.097	-0.654	0.319	3.538	4.720
USC-13	3.960	4.645	-0.685	0.284	4.066	5.214
Geom. Mean	1.488	1.857				
Std.Dev.	0.967	1.101				
USHS/DE-58	1.000	1.442	-0.442	0.233	1.028	1.867
USHS/DE-48	1.000	1.446	-0.446	0.230	1.039	1.867
USHS/DE-60	2.044	2.635	-0.592	0.272	2.117	3.138
USHS/DE-46	7.515	9.469	-1.954	0.838	7.717	11.000
Geom. Mean	1.980	2.686				
Std.Dev.	3.123	3.855				
Overall Geom. Mean	1.775	2.202				
Overall Std. Dev.	1.803	2.201				

Source: Authors calculations

Table 4: Efficiency Estimates by category, Model 1 (cont.)

Table 5: Efficiency Estimates by category, Model 2.

University Type	Efficiency Estimate (EFF)	Efficiency Estimate Bias-corrected (C-EFF)	Estimated bias (Est-Bias)	Estimated Std (Est-Std)	Confidence Interval: lower bound (LB)	Confidence Interval: upper bound (UB)
ING-30	1.000	1.300	-0.300	0.131	1.026	1.516
ING-9	1.099	1.340	-0.241	0.115	1.119	1.533
ING-3	1.000	1.340	-0.340	0.146	1.028	1.557
ING-36	1.000	1.355	-0.355	0.160	1.025	1.582
ING-35	1.000	1.395	-0.395	0.208	1.031	1.741
ING-24	1.224	1.525	-0.302	0.129	1.261	1.755
ING-32	7.036	8.045	-1.009	0.495	7.146	9.038
Geom. Mean	1.379	1.769				
Std.Dev.	2.263	2.522				
UPAM-18	1.000	1.256	-0.256	0.129	1.032	1.491
UPAM-31	1.000	1.269	-0.269	0.118	1.027	1.477
UPAM-23	1.000	1.342	-0.342	0.152	1.030	1.568
UPAM-14	1.000	1.352	-0.352	0.156	1.026	1.557
UPAM-22	1.112	1.383	-0.270	0.123	1.147	1.600
UPAM-21	1.179	1.480	-0.301	0.136	1.206	1.713
UPAM-50	1.592	1.938	-0.346	0.173	1.629	2.248
UPAM-55	2.018	2.337	-0.320	0.144	2.069	2.618
UPAM-2	2.056	2.572	-0.516	0.234	2.118	3.020
UPAM-7	2.356	2.610	-0.255	0.148	2.376	2.932
UPAM-41	2.145	2.668	-0.522	0.246	2.191	3.077
UPAM-71	2.607	2.944	-0.337	0.182	2.646	3.312
UPAM-59	2.558	3.151	-0.593	0.265	2.636	3.646
Geom. Mean	1.547	1.908				
Std.Dev.	0.645	0.711				
UPSM-25	1.000	1.322	-0.322	0.137	1.029	1.525
UPSM-17	1.000	1.326	-0.326	0.142	1.026	1.546
UPSM-10	1.062	1.351	-0.289	0.127	1.087	1.571
UPSM-4	1.000	1.389	-0.389	0.193	1.022	1.687
UPSM-49	1.000	1.413	-0.413	0.227	1.028	1.858
UPSM-12	1.143	1.435	-0.291	0.129	1.175	1.656
UPSM-43	1.438	1.786	-0.348	0.152	1.481	2.059
UPSM-61	2.026	2.244	-0.219	0.122	2.057	2.524
UPSM-38	1.841	2.265	-0.424	0.236	1.877	2.723
UPSM-1	2.193	2.630	-0.437	0.230	2.230	3.093
UPSM-62	4.549	5.692	-1.143	0.522	4.681	6.717
UPSM-52	5.619	6.439	-0.819	0.401	5.690	7.205
UPSM-74	8.225	10.543	-2.318	1.399	8.387	13.413
Geom. Mean	1.851	2.336				
Std.Dev.	2.263	2.807				

University Type	Efficiency Estimate (EFF)	Efficiency Estimate Bias-corrected (C-EFF)	Estimated bias (Est-Bias)	Estimated Std (Est-Std)	Confidence Interval: lower bound (LB)	Confidence Interval: upper bound (UB)
USC-68	1.000	1.265	-0.265	0.128	1.029	1.494
USC-34	1.000	1.316	-0.316	0.152	1.033	1.602
USC-5	1.000	1.332	-0.332	0.146	1.030	1.560
USC-69	1.000	1.342	-0.342	0.154	1.028	1.593
USC-73	1.000	1.347	-0.347	0.161	1.023	1.603
USC-64	1.000	1.367	-0.367	0.174	1.024	1.630
USC-51	1.211	1.422	-0.211	0.091	1.251	1.591
USC-37	1.182	1.463	-0.280	0.141	1.222	1.740
USC-33	1.305	1.582	-0.277	0.117	1.340	1.803
USC-42	1.315	1.626	-0.311	0.143	1.355	1.902
USC-26	1.386	1.721	-0.336	0.143	1.438	1.982
USC-65	2.490	3.077	-0.588	0.260	2.558	3.533
USC-54	3.444	4.100	-0.656	0.332	3.542	4.741
USC-13	3.829	4.603	-0.774	0.310	3.940	5.176
Geom. Mean	1.437	1.815				
Std.Dev.	0.978	1.138				
USHS/DE-58	1.000	1.400	-0.400	0.223	1.033	1.854
USHS/DE-48	1.000	1.413	-0.413	0.222	1.037	1.855
USHS/DE-60	2.044	2.600	-0.557	0.271	2.097	3.110
USHS/DE-46	2.926	3.697	-0.771	0.407	2.977	4.430
Geom. Mean	1.564	2.088				
Std.Dev.	0.930	1.101				
Overall Geom. Mean	1.553	1.961				
Overall Std. Dev.	1.537	1.836				

Table 5: Efficiency Estimates by category, Model 2 (cont.)

Table 6: Determinants of (in-) efficiency differentials

(Truncated, bootstrapped second-stage regression, inefficient score)

Variables		CI-90%		CI-95%		CI-99%	
	Estimates	LB	UB	LB	UB	LB	UB
Age	-0.128*	-0.170	-0.078	-0.207	-0.023	-0.330	0.183
Size	-4.843***	-5.370	-4.210	-5.781	-3.888	-7.589	-3.186
Regional GDP	1.644***	1.406	1.914	1.173	2.165	0.637	2.745
Regional Public R&D Expenditure	-0.437**	-0.509	-0.310	-0.612	-0.178	-0.929	0.202
Regional Private R&D Expenditure	-2.091**	-2.597	-1.668	-2.880	-1.443	-3.885	-0.834
Growth Rate Regional GDP (%)	0.020**	0.016	0.022	0.012	0.026	-0.009	0.036
Growth Rate Public R&D Expenditure (%)	0.041**	0.033	0.046	0.026	0.049	-0.002	0.075
Growth Rate Private R&D Expenditure (%)	-0.402***	-0.427	-0.382	-0.444	-0.382	-0.535	-0.365
H	5.644***	4.739	6.070	4.427	6.749	3.455	9.072
ING	-0.259***	-0.326	-0.150	-0.407	-0.045	-0.738	0.493
UPAM	0.684**	0.536	1.094	0.377	1.431	-0.368	2.185
UPSM	8.233***	6.792	9.985	6.322	11.019	5.686	13.380
USC	-0.019*	-0.025	-0.010	-0.033	0.000	-0.056	0.024
USHS	13.940***	11.951	16.114	11.574	17.100	10.616	20.010
σ_{ε}^{2}	4.939***	4.802	5.401	4.657	5.760	3.978	6.667

Notes:

*=statistically significant at 90%

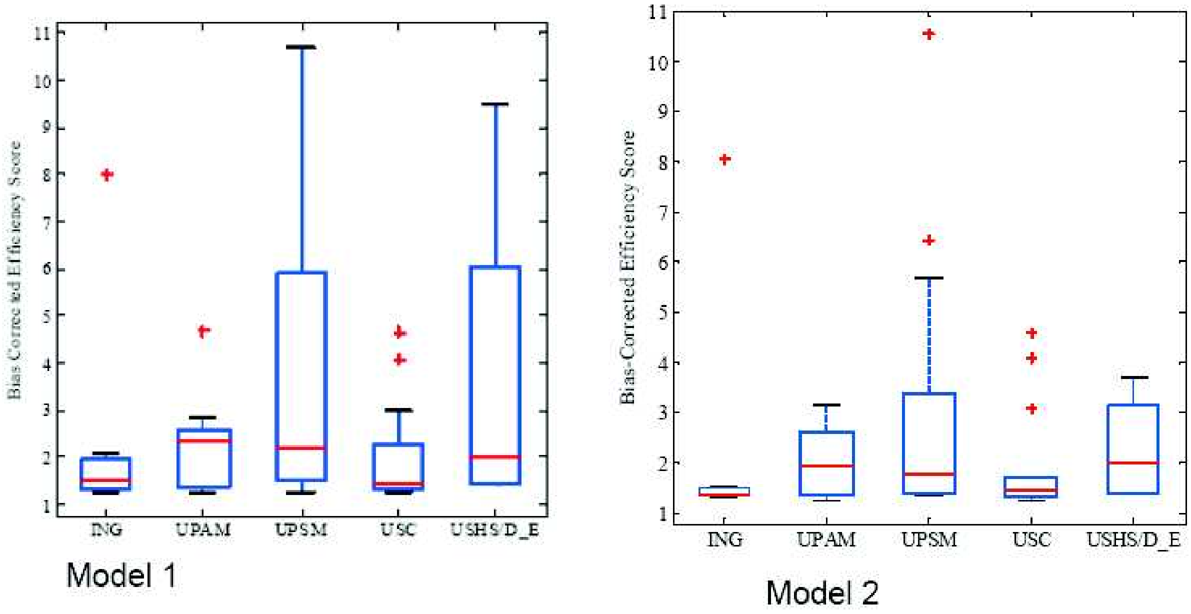
**= statistically significant at 95%

***= statistically significant at 99%

Note: The variables Public and Private expenses in R&D are highly correlated. Therefore the model has been estimated using these variables one at time.

Figures of the paper

Figure 1: Boxplots of bias-corrected efficiency scores by category.Model 1(left panel) and Model 2 (right panel)



Model 1

Model 2

Documents de travail du BETA

2012–**01** *Unanticipated vs. Anticipated Tax Reforms in a Two-Sector Open Economy*
Olivier CARDI, Romain RESTOUT, janvier 2012.

2012–**02** *University Technology Transfer: How (in-)efficient are French universities?*
Claudia CURI, Cinzia DARAIO, Patrick LLERENA, janvier 2012.

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