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The productivity of French Technology Transfer Offices after government reforms

Claudia Curi, Cinzia Daraio,
Patrick Llerena

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Claudia Curi
Faculty of Economics and Management,
Free University of Bolzano-Bozen
email: claudia.curi@unibz.it

Cinzia Daraio
Department of Computer, Control and Management Engineering Antonio Ruberti,
University of Rome "La Sapienza"

Patrick Llerena
University of Strasbourg, BETA (Bureau d'Economie Théorique et Appliquée) and
Observatoire des Sciences et Techniques (OST, Paris)

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Abstract

This paper assesses the productivity change of the French Technology Transfer Offices (TTOs) after the introduction of the July 1999 Innovation Law and the New Public Management Oriented Reform. By using Data Envelopment Analysis (DEA)-based Malmquist Productivity Index, we find an average increase in the short-term productivity of the French TTOs driven by both positive efficiency and technology change. The bootstrap analysis reveals that these improvements are ascribed to 50% of the TTOs system, while the remaining part does not show significant changes. Moreover, while older TTOs positively contribute to the performance of French TTOs in the short run, young TTOs with hospital seems to contribute negatively to the efficiency of the entire system.

Keywords: Technology Transfer Offices (TTOs), French University System, Malmquist Productivity Index, Data Envelopment Analysis (DEA), Bootstrap. JEL Classification: C14; D24; I29; O32.

1. Introduction

It is well known that university technology transfer plays a decisive role in the development and growth of local and national economic development (e.g.; Caldera and Debande, 2010). Over the past two decades, almost all European countries have passed through a transition period that has been accompanied by the institutionalization of Technology Transfer Offices (TTOs), namely those special-purpose organizations in charge of transferring technology, and regulatory interventions (European Commission, 2004, 2008). As today, it is unclear whether EU Technology Transfer Offices (TTOs) have received a boost in productivity after the introduction of policy interventions, as there is very limited analysis on this matter due to a lack and heterogeneity of EU data (Bonaccorsi and Daraio 2007a,b; Daraio *et al*. 2011).

The aim of this paper is to contribute to the current debate of TTOs' performance in Europe by analysing the productivity of the French TTO system. Contrary to other countries (i.e. the UK, the US, Japan and Germany [i.e. Etzkowitz, 1998; Philpott *et al.* 2011; Miller *et al.* 2012]), the French national government has delayed reforms to formalize university technology transfer activities. However, two main reforms have been undertaken since 1999. The *July 1999 Innovation Law* constitutes the main policy decision and is aimed at enhancing technology transfer processes between universities and industry. After its introduction, the number of TTOs flourished. In 2001, the *New Public Management Oriented Reform* was introduced to accelerate and improve the quality of the technology transfer process. This intervention includes: (i) the definition (and development) of the funding scheme based on TTOs' performance; (ii) the identification of the key drivers of TTOs' performance and (iii) the definition of the metrics aimed at monitoring the efficiency of public spending, particularly in the science and technology field. The metrics include patent applications as well as patent extensions and similar intellectual property rights instruments for software (Bach and Llerena 2007).

After the introduction of the reforms, all types of metrics have registered an increase in number, which have been interpreted as good performance indicators of the entire French TTOs. However, the simple increase in these metrics cannot support evidence of substantial productivity growth of the French TTOs technology transfer process to draw conclusions on whether the system underwent a real productivity. This because the French TTOs technology transfer process is a complex process characterized by anomalies in the output production and differences related to the TTOs affiliated university, age and presence of a hospital.

First, compared to other countries such as the US and the UK, the French technology transfer process is at its early development as characterized by outputs which are produced intermittently and it does not include the ‘marketing stage’ of the product. Second, for some universities, the presence of TTO internal to university is not a new concept as, before 1999, some universities developed their own organizations, although not institutionalized, in charge of technology transfer. For this set of TTOs, the production process is more mature compared to the new TTOs and outputs are produced at higher frequency. The increase in output production is not homogenous across the different university categories the TTO belongs to as well across type of outputs. For instance, TTOs related to Engineering Schools increased their production of patent applications over time and produced higher amount than the Polyvalent Universities with Medical School. However, they produced less amount of patent extension compared to UPAM. Lastly, the presence of a hospital is not strictly related to a medical school but, for instance, universities specialising in science (Science Universities) may have both medical schools and university-related hospitals, while Polyvalent University may have only a medical school. Universities with related hospitals carry out significant ongoing medical research, whereas universities with medical schools are more involved in training activities.

This paper attempts to contribute to the scarce literature of TTOs in Europe by analyzing the productivity growth of French TTOs after the introduction of the two government reforms. The aim is to shed light on how TTOs responded in the short term productivity to these policy interventions. We use a unique panel data available for the French university system (Bach and Llerena 2008, 2010)[1], which is comprehensive enough to carry out a productivity assessment based on Malmquist Index (Färe *et al.* 1994).

For the specific case of TTOs, the productivity of a TTO is a measure of the best organizational and managerial practices that allow producing the maximum feasible level of outputs given available input resources. Malmquist Productivity Index, computed through the Data Envelopment Analysis (DEA), allows estimating the productivity change and its main drivers, namely efficiency and technological change. While the efficiency change refers to possible improvements (or deteriorations) in business practices through approaching (or moving away from) the best organizational and managerial practices (i.e.; the frontier), the

[1] It is worth mentioning that these are the most recent data available on the French university TTO system as the French government has stopped collecting these data.

organisational and technical change refers to the possible improvements (or deterioration) of the best organizational and managerial practices through output mix expansion (or decreases) (i.e. expansion or reduction of the technological frontier) given the resources (inputs) used. In this study we extend the use of Malmquist Index, already applied in several fields and also in the TTOs efficiency estimation (Thursby and Thursby 2002; Kim 2011), to the bootstrapped Malmquist Productivity Index (Simar and Wilson 1999). By using the bootstrapping technique, we are able to uncover information on the actual changes occurred in the French TTOs system and excluding those inducted by sampling variation, which would lead to a biased estimation. In other terms, our approach provides a productivity and efficiency assessment based only on the real changes in productivity.

Summing up, we attempt to fill the gap existing in the literature by providing the first country-level assessment of performance of the young system of TTOs operating in Europe based on output indicators brought about by the governmental reforms of the early 2000s.

We address the following main research questions: 1) Did French TTOs experience positive efficiency and technological gains right after the introduction of the government reforms?; 2) Is there any group of TTOs (in terms of university category, age and presence of a hospital) able to boost the productivity of the entire system in the short term?

The paper is organized as follows. Section 2 provides a selected overview of the literature, and Section 3 describes the methodology applied. Section 4 describes the data, and Section 5 discusses the main results. Section 6 concludes.

2. A selected review of the literature

The empirical literature related to the analysis of the production process productivity of TTOs is minimal and focuses on US data and covers different time spans. The pioneer paper (Thursby and Thursby, 2002) investigates the main drivers of the productivity growth of 65 US universities over the period 1994–1997 by using a linear three-stage process[2] and DEA Malmquist Productivity Index. They found that increased licensing was due primarily to an increased willingness of faculty and administrators to license and increased business reliance on external R&D rather than a shift in faculty research.

The second paper, by Kim (2011), extends the previous analysis to a sample of 90 US TTOs by tracking the year-to-year productivity growth over the period 1999–2007. The author considers the technology transfer process as one-stage process and finds that there was

[2] More specifically, invention disclosure is the output of the first stage, patents application is the output of the second stage and licenses and option agreements are the outputs of the third stage).

substantial competence demonstrated in the productivity growth of US university technology transfer activities for the period 1999–2007, contrary to the previous research findings. These positive gains in productivity are ascribed to the increasing willingness of universities to improve commercialization to gain a high return on investment. However, the author does not disentangle the sources of productivity growth.

There is a broader literature, however, on the factors which affect the TTO's efficiency. With regards to specific characteristics of different university categories, several papers (e.g. Thursby and Kemp, 2002; Curi *et al.* 2012) find efficiency disparities across TTO groups attributable to university production specialization (such as basic research vs. applied research vs. teaching) rather than to competencies in licensing. More specifically, it is generally assumed that universities with medical schools are likely to be more efficient than those without because it is easier for them to conduct clinical trials and produce a large number of university licenses related to biomedical inventions. Thursby and Thursby (2002) find that the presence of a medical school positively affects the performance of US TTOs at the invention disclosures and patent applications stages but negatively affects performance at the last stage of license agreements, whereas Kim (2011) shows that the presence of a medical school does not by itself guarantee high productivity in technology transfer. It is also generally assumed that a TTO could benefit from a 'learning by doing' experience which is directly proportional to its seniority. However, the empirical evidence shows that it might play a dual role, depending on the strategies pursued by the TTO's management. Siegel *et al.* (2003) and Curi *et al.* (2012) show that older US and French TTOs, are more efficient. However, Siegel *et al.* (2008) find opposite results. Thursby and Thursby (2002) do not find any evidence on the importance of learning by doing. Table 1 summarizes the main results of nine selected studies based on both efficiency and productivity assessment that are related to the literature discussed in this paper.

The present paper attempts to assess the productivity growth of EU TTOs using France as a special case with the aim to uncover evidences on the statistically significant changes of Malmquist Productivity Index (and relative components) in terms of TTOs groups and TTO's specific characteristics, namely affiliated university, age and presence of a hospital. Because this more resilient methodology allows disentangling the heterogeneity across TTOs groups, it should be effective for clarifying the actual effect of efficiency change and/or technological change on productivity and how they have responded to the French policy intervention in the short-run.

[TABLE 1 AROUND HERE]

3. The methodology

We examine productivity change through a Malmquist Productivity Index (Färe *et al.* 1994) approach based on efficiency measures computed through Data Envelopment Analysis (DEA). DEA is a non-parametric estimator of the efficient frontier and determines the benchmark against which to compare the performance of each TTO. The distance of a TTO from the frontier indicates its inefficiency score (Farrell 1957). The productivity change (hereafter indicated by M which stands for Malmquist) can be decomposed in efficiency change (EC) and organisational and technical change (TC). The efficiency change captures how close (or far) the TTOs move to (or away from) the frontier and informs about the possible catching-up of TTOs. The organisational and technical change captures the shift upward (or downward) of the frontier and informs about possible new business practices adopted by TTOs. From a practical viewpoint, the DEA-based Malmquist Index is very useful to carry out our analysis as: (i) it does not impose any assumption on the functional form of the production frontier, (ii) it allows for the simultaneous use of multiple inputs and outputs and (iii) it does not require the knowledge of financial information, which is not available for the French TTO database.

Until recently (see, e.g., Thursby and Thursby 2002; Kim 2011), DEA has been applied as a simple linear programming approach to estimate efficiency scores without any statistical investigation on their significance. The novelty of this study from a methodological viewpoint is to perform the TTO productivity assessment within an inferential setting, adopting the bootstrap procedure suggested by Simar and Wilson (1999). The crucial advantage of this approach is the removal of bias from each estimate so that we are able to derive bias-corrected estimates (BC-M, BC-EC, and BC-TC), as well as the identification of confidence intervals for each estimate so to derive the statistical significance of each (at a given level of significance α %).

The production model is based on the assumption that French TTOs share a common production frontier and promote the maximization of their commercial outputs and is in line with the policy objective introduced by the two main reforms (see the Introduction section). We compute a Malmquist output-oriented index (M) for each TTO *i,* between time t_1 and t_2 as follows:

$$M_i^{t_1,t_2} = \frac{D_i^{t_2,t_2}}{D_i^{t_1,t_1}} \times \left(\frac{D_i^{t_2,t_1}}{D_i^{t_2,t_2}} \times \frac{D_i^{t_1,t_1}}{D_i^{t_1,t_2}} \right)^{0.5} = EC_i^{t_1,t_2} \times TC_i^{t_1,t_2} \qquad (1)$$

where $D_i^{t_1,t_1} = D_i^{t_1,t_1}(x_i^{t_1}, y_i^{t_1})$ is the Farrell output distance (i.e. the maximum proportional expansion of the outputs given the inputs used, see Farrell, 1957) of each TTO *i* at time t_1 relative to the technology at time t_1, and $D_i^{t_1,t_2} = D_i^{t_1,t_2}(x_i^{t_1}, y_i^{t_1})$ is the distance relative to the technology at time t_2. $D_i^{t_2,t_1} = D_i^{t_2,t_1}(x_i^{t_2}, y_i^{t_2})$ and $D_i^{t_2,t_2} = D_i^{t_2,t_2}(x_i^{t_2}, y_i^{t_2})$ are respectively the distance of each TTO at time t_2 to the technology at time t_1 and t_2. The two components of the Malmquist indices are $EC_i^{t_1,t_2}$ and $TC_i^{t_1,t_2}$, which represent the efficiency change and technological change, respectively.

$M_i^{t_1,t_2}$, $EC_i^{t_1,t_2}$ and $TC_i^{t_1,t_2}$ greater (less) than unity indicate *regress* (*progress*) between times t_1 and t_2. Values equal to unity indicate *no change*.

However, relation *(1)* does not allow determining whether changes in productivity, efficiency and technology are real or merely artifacts of the fact that we have to estimate the production frontiers because we do not know the true ones (Simar and Wilson, 1999). Thus, we employ a consistent bootstrap estimation procedure for correcting for the bias and obtaining the confidence intervals on $M_i^{t_1,t_2}$, $EC_i^{t_1,t_2}$ and $TC_i^{t_1,t_2}$. The idea underlying this approach is to generate a sequence of pseudo datasets to obtain bootstrap estimates for each estimate by using the bivariate kernel density estimation-where the bandwidth is selected following the normal rule of thumb- and the adaptation of the reflection method. From the bootstrap sample associate to each estimate, we compute the bias-correction terms and the confidence intervals by selecting the appropriate percentiles[3]. Now, we test whether changes are statistically significant. In particular, if a confidence interval contains the unity (that means no change), then the change turns out to be not statistically significant; whereas if the confidence interval does not contain the unity, then the change turns out to be statistically significant. Only estimates that fall into the latter category are considered in the evaluation of the productivity growth because they carry statistical significance and are not the result of sampling variation (for technical details, see Simar and Wilson, 1999).

[3] More details on the bootstrap procedure are available upon request.

4. Data description

Our sample consists of a balanced data panel of French TTOs collected by BETA (Bureau d'Economie Théorique et Appliquée, UMR UdS-CNRS 7522, Strasbourg) with the support of the national French TTO network (CURIE), the Conference of University Rectors (CPU) and the Association of Engineering Schools Directors (CDEFI) from the years 2005 and 2007[4].

We evaluate the French TTO system adopting the operational perspective as indicated by French law. We thus distinguish between "core output", which includes patent applications (PAT_APP), and "ancillary output", which includes number of patents with submitted extension requests (PAT_EXT), number of extensions required (Nb_PAT_EXT) and software applications (SW_APP). As inputs, we select labour, proxy by the number of full-time equivalent employees (ETP), as the main means which enables a TTO to operate. In addition, we select the knowledge, proxied by the scientific publications (PUB), produced by the affiliated university, which is considered as some kind of 'raw' material at the TTO's disposal.

We model the technology transfer process of French TTOs at their early stage of development by accounting for the mismatching in the production process due to outputs produced at a very slow pace (i.e. discrete output flow), while inputs used at a continuous flow. By assuming a 'two-year production cycle', that is two years from the start of input usage to deliver the output, we construct the production model as follows. On the input side, we select the average inputs used over two consecutive years in line with previous papers (e.g. Thursby and Kemp 2002; Anderson *et al.* 2007; Curi *et al.* 2012), while on the output side we select the cumulative output production over two consecutive years. In this way, we reduce the error from time lags. From an empirical point of view, this model wipes out two changes, limiting the analysis to one productivity change, namely the period 2003–2004 vs. the period 2005–2006.

In terms of sample composition, we include TTOs active in the production of at least patent application activity (the core output) and one of the remaining activities. We end up with a database of 30 TTOs covering all the French university categories[5], except the social science and humanities, law and economics universities because their production is close to zero in all the technology transfer activities. Our sample is well representative of the entire

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

[5]They are: *i*) Engineering School (ING), (*ii*) Polyvalent University with Medical School (UPAM); (*iii*) Polyvalent University without Medical School (UPSM) and (*iv*) Science Universities (USC).

sector as: (i) PAT_APP constitutes 94.23% and 94.56% of the total PAT_APP over the two periods, respectively; and (ii) the remaining outputs represent 94.15% and 96.67% of the total production of the ancillary outputs over the two periods, respectively.

Table 2 presents the summary statistics of the input and output variables associated with the pooled sample over the two periods 2003–2004 and 2005–2006, according to the categories of the disciplinary fields of the related universities. We discuss the ancillary output broken down into its components to better understand how French TTOs diversified their outputs during the periods under analysis. These statistics enlighten a general increase in SW_APP for all TTO categories-except for UPSM and a decrease in PAT_APP for some university categories[6]. Only Engineering School (ING) shows a considerable positive growth (i.e. 18.75%) in PAT_APP. Decrease in PAT_EXT and NB_PAT_EXT are also registered in most of university categories, expect for UPSM. We observe a considerable increase in the average amount of ETP[7] along with a modest increase in the amount of stock of PUB.

[TABLE 2 AROUND HERE]

In terms of distributions of input and output usage, not surprisingly, USC universities employ, on average, the largest amount of ETP and have the largest amount of technology stock. USC universities produce, on average, the largest amount of patent applications, as well as the largest amount of the remaining activities. ING and UPAM, on average, seem to have similar patent application production over the period 2003–2004 but not in the following period. Evidence in output variability is particularly found across USC TTOs.

We classify TTOs into TTOs with and without hospitals as well as TTOs that are young versus those that are mature. In contrast to other studies, we do not consider the TTO's ownership (private vs. public) as all French TTOs are related to public universities. On the other hand, the TTOs' seniority, measured as the length of time that has passed since the creation of the technology transfer office, accounts for possible 'learning by doing' effects in technology transfer activity. In fact, older TTOs could benefit from their experience compared to younger TTOs. We could, thus, expect a positive impact on TTOs' efficiency if, for instance, TTOs learn to focus their strategies of technology transfer on transforming the 'best' inventions into patents and hence produce a source of income afterward. In addition, in France, there are USC universities with both medical schools and university-related hospitals, while UPAM universities may have only medical schools. It is, therefore, more informative

[6]Namely, UPAM is the category that suffers the most (-38.21%), followed by USC (-20.71%) and UPSM (-18.18%).
[7]Namely, by category, UPSM (+63.64%), UPAM (+56.47), ING (+35.36%) and USC (+30.47%).

in the French case to control for the presence of a university-related hospital. The presence of a university-related hospital might guarantee significant ongoing medical research, whereas a simple medical school might have only training activity. It is usually thought that medical research is an important source of technology transfer. However, it might happen that institutions, universities and university-related hospitals, which are legally independent entities, try to capture the potential technology transfer coming from the life and medical sciences. For this reason, the impact of the presence of university-related hospitals is ambiguous and might depend on the competition between the two institutions (namely the university and the university-related hospital). According to the literature, in fact, results are uncertain and, in the French case, Curi *et al.* (2012) find that the presence of a university-related hospital is detrimental to efficiency.

[TABLE 3 AROUND HERE]

Table 3 shows a descriptive analysis of the variables AGE and HOSPITAL across TTOs grouped in different disciplinary fields. It appears that ING (i.e. engineering universities) are the most experienced (mean: 18.67 years), while UPSM universities (i.e. polyvalent universities without medical schools) are the youngest. The presence of a hospital, in contrast, is a specific characteristic associated with UPAM and USC universities.

These evidences show the heterogeneity within the French TTOs system and reinforce the use of our methodological approach rather than the use of an analysis based on simple nominal growth rate, which fails to capture the multiple dimensions of TTO production.

5. Empirical results

Before carrying out the TTOs productivity assessment, we formally test if the frontier globally exerts constant, non-increase or variable returns to scale (Simar and Wilson 2002), acknowledging that if the technology exhibits variable returns to scale (VRS), then the Malmquist Productivity Index is a biased estimate of productivity change (Grifell-Tatjé and Lovell, 1995) and alternative indices have to be used. Since our analysis is based on the evaluation of two frontiers (one for the period 2003-2004 and the other one for the period 2005-2006), we perform two tests. We fail to reject H_0 hypothesis at 5% confidence level for both frontiers (*p*-values are equals to 0.192 and 0.1490 respectively, thus both greater than

0.05), accepting global CRS[8]. Given these results, we can assume constant returns to scale frontiers and thus use the Malmquist Productivity Index in our productivity assessment.

Regarding the peculiarities and heterogeneity between the groups of the French TTOs, presented in the previous section, we report the geometric mean of the efficiency change, the technical change and the Malmquist Productivity Index, aggregated according to the entire system, university category, presence of a hospital and relative age. Following our aim of uncovering the actual productivity (efficiency and technological) change, we compute the geometric mean (i.e.; *Geom.Mean-all*) including all the estimates (both statistically significant and not) from the set of TTOs under investigation and compare against the geometric mean of only those estimates with statistical significance (i.e. *Geom.Mean-subset*) which carry economic meaning. Estimates are reported bias-corrected and expressed à la Farrell so that scores greater than one implies a decline while scores less than one imply a growth. Changes in productivity expressed in percentages are computed as the difference between one and the Farrell scores.

[TABLE 4 AROUND HERE]

Table 4 shows an overall increase (6.26%) in productivity over the period 2003-2006 of the French TTOs system as a whole. This finding is consistent with the productivity growth associated with each TTO university category, except for USC TTOs which experience an average decline of -7.1%. This can be ascribed to that fact that USC TTOs are the only category which experience decline in both outputs (PAT_APP and ANC_OUT) of the technology transfer process. In line with Thursby and Thursby (2002) for US TTOs at their early stage of development, the overall productivity gain seems to be driven by positive organizational and technological change (23.99%) which is, however, dampened by negative efficiency change (-15.8%).

Although there is evidence of overall positive productivity growth associated to each group, efficiency and technological changes seem to have played difference roles between groups. ING and UPSM universities experienced positive change in both efficiency and technology. On the other hand, TTOs associated with UPAM and USC experience, on average, positive technological change but negative efficiency change leading to a gain in productivity for UPAM and a decline in productivity for USC. Following Thursby and

[8]This finding is different from the finding presented by Curi *et al.* (2012) because of the different TTOs sample composition. For instance, in this paper we exclude TTOs associated to social science and humanities, law and economics universities while they are included in Curi *et al.* (2012).

Thursby (2002), we distinguish between universities with and without hospitals[9] (Table 5) as possible source of productivity heterogeneity might be found between these two groups due to differences in the commercialization process strategies. Our findings show that French TTOs without hospitals register positive changes in efficiency and technology while TTOs with hospitals register positive change only in technology.

The last investigation is with respect to TTOs' seniority (Table 6). Mature (older than seven years old[10]) and young TTOs seem to perform according to different patterns. Young TTOs deteriorate in efficiency but improve in technology, whereas older TTOs exhibit positive changes in both efficiency and technology.

Thus, it seems that, after the introduction of the policy reforms, the French TTOs system responded with positive productivity change but suffered from deterioration in efficiency rather than in technology. This might be ascribed to the fact that there are TTOs, mostly young TTOs, lagging behind and finding difficulties in catching-up the best business practices of the older TTOs. Also, the presence of a hospital hinders the adoption of best business practices. On the other hand, the introduction of new legislation encourages TTOs to become more competitive in improving their business models in terms of organisation and technology.

Turning to the results for the bias-corrected actual values (estimation based on confidence intervals), we more precisely find that 14 TTOs (47% of the sample) do not experience significant change in efficiency and 23 TTOs (77%) do not experience technological change. These results suggest that contrary to the simple point estimates used below, only few TTOs positively improve their business models in terms of organisation and technology while the majority of French TTOs are subjected to efficiency change (both positive and negative). More specifically, the majority of ING and UPSM TTOs do not show change either in efficiency or in technology. Among UPAM TTOs, five and seven out of 12 do not show significant changes in efficiency and technology, respectively. Among USC TTOs, four out of 12 do not change in their efficiency and any of USC TTOs experience technology change. This analysis based on the statistical significance of changes uncovers that the entire system as a whole is not sensitive to productivity change but it could be identify a small group of TTOs that experienced real positive technology change and a larger one sensitive to

[9]This because in France there are Science Universities with both medical schools and university-related hospitals, while a Polyvalent University with a Medical School may have a medical school without a hospital (see Table 5).

[10]We assume seven years as the minimum age for TTOs to be considered mature. We compute sensitivity analysis on our estimates assuming age ranging between 5 and 9. Results do not change.

efficiency change. Taken together, it suggests that the almost half of the French TTOs system (54%) improves the productivity in the short run while the remaining part is divided into a group that shows any productivity change (16%) and the other group (30%) deteriorates its productivity.

With respect to the presence of a hospital, the analysis based on the confidence interval reveals that efficiency and technological changes associated with TTOs without hospitals are not statistically significant. On the contrary, TTOs with hospitals register statistically significant changes in efficiency, both positive and negative and positive technological changes for some of them. These findings confirm the different nature of business models adopted the two forms of TTOs.

[TABLE 5 AROUND HERE]

With regards to the seniority of TTOs, the statistical analysis of efficiency and technological change shows that within mature and young TTOs, it is possible to identify a subset of TTOs which exhibit significant changes. However, while young TTOs register a negative efficiency change, the older TTOs show efficiency gains. Regarding the technological change, mature and young TTOs exert positive gains in technology.

[TABLE 6 AROUND HERE]

Overall, it seems that the French TTO system responded positively to the introduction of the government interventions as 50% of TTOs improved their productivity through improvements in technology and efficiency. Among the different TTO categories, UPAM TTOs are the most active in improving their business models as well as operational efficiency, along with USC TTOs. However, ING and UPSM TTOs show stable productivity behaviour. Our finding highlights the presence within the French TTOs system of a subset of TTOs which proactively reacted to the national reforms. This implies that further policy measures are desirable to enhance the productivity of those TTOs facing problems in changing up with best practise and those which need more stimulas to make process.

To investigate the equality in productivity change, we look at the distributions of DEA estimates of Malmquist Index (M) efficiency change and organisational and technical change associated with each French TTO. Fig. 1 distinguishes between university categories and according to the presence of a hospital. Looking at Fig. 1, mixed evidence is found with respect to efficiency change (top panel). ING TTOs perform statistically differently, while within UPSM we find no differences. However, within the UPAM and USC categories, TTOs are clustered into four groups, which perform similarly within each group, respectively.

With respect to the presence of a hospital, we observe heterogeneity in performance within the UPAM and USC groups. In addition, if we compare UPAM TTOs with hospitals to USC TTOs with hospitals, we do not find statistically significant differences. Thus, we cannot statistically conclude that the differences between TTOs' efficiencies can be entirely attributable to the presence of a hospital. On the other hand, the technological change distributions show that, to a large extent, TTOs perform similarly. This might suggest that in the short term, technological change does not depend strictly on the category nor on the specific characteristics.

[FIGURE 1 AROUND HERE]

Fig. 2 reveals other interesting aspects. It shows a lack of systematic differences between young and older TTOs; in the same way, there is a lack of systematic differences between TTOs with and without hospitals. For some categories, such as ING and UPSM, older and young TTOs seem to perform similarly to a large extent. However, if we compare Figs 1 and 2, we can observe that young TTOs associated with hospitals exert the highest negative efficiency change. Thus, we cannot statistically conclude that the differences in TTOs' efficiencies can be entirely attributable to the age of the TTOs.

The difference in efficiency change we found might pick up some specific TTOs' characteristics that go beyond category, age and the presence of a hospital. For instance, difference in efficiency change might be due to specific characteristics of the related university, such as whether or not the university is well established or young. This needs further research.

[FIGURE 2 AROUND HERE]

6. Conclusions

This paper is intended primarily to examine the productivity of European TTOs after the introduction of the major reforms of the early 2000s. Empirical evidence is provided by using a unique and original dataset on the French TTOs system collected by BETA (University of Strasbourg) over the period 2003–2006. The novelty is twofold: first, this is the first productivity assessment of the French TTOs system; second, this is the first study wherein productivity changes and its components are assessed in an inferential setting.

We focus our analysis on a short time period, namely 2003–2006. The use of bias-corrected indices revealed a positive productivity change, driven by efficiency and technology changes. Moreover, the analysis of the confidence intervals suggest that the productivity have been changed significantly only for half of the TTOs. In addition, TTOs seems more sensitive to efficiency changes than to technological changes, as most-TTOs did not improve their business models. Furthermore, TTOs with hospitals seem to contribute the most to performance changes. While older TTOs positively contribute to the performance of French TTOs in the short term, young TTOs with hospital seem to contribute negatively to the efficiency of the entire system.

This study confirms that the productivity of TTOs is more affected by their operational efficiency rather than their ability in improving their business models. However, the stimulus provided by the reforms enabled some TTOs to push upward the frontier. The combination of seniority and presence of a hospital constitute an obstacle to reap productivity gain in the short run. More policy actions are needed in this regard.

A possible area for future research could be to provide a wider analysis across countries of the determinants of productivity growth by examining the relationship between government policy and TTOs strategy on the main components of productivity change.

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Tables of the paper

Table 1: Selected results from the literature on TTOs' efficiency and productivity

TTOs	Number of outputs	Authors	Output used	MED	AGE	PUB	GROUP [a]
			Efficiency analysis				
France	Multiple	Curi *et al.* 2012	Patent and software applications, patents with submitted extension requests, number of extension required	-	+		yes
US	One	Siegel *et al.* 2003 Anderson *et al.* 2007	Number of licenses	ne	ne	ne	
			Licensing income	ne	+	ne	
	Multiple	Thursby and Kemp 2002	Number of licenses, patent applications, invention disclosures, amount of royalties and industry sponsored research	-		+[b]	yes
UK	One	Chapple *et al.* 2005	Number of licenses	ne	+		
			Licensing income	-	ne		
Spain	One	Caldera and Debande 2010	Number of licenses	ne	ne	-	ne
			Licensing income	ne	+	ne	+
US & UK	Multiple	Siegel *et al.* 2008	Number of licenses, income from licenses, university start-ups	+	-		
			Productivity analysis				
US	One	Thursby and Thursby 2002	Invention disclosures, Patent applications, Licenses executed	+	ne		
	Multiple	Kim 2012	Number of patents, Number of licenses, License income	ne			

Notes: MED = medical school; AGE = TTO age; PUB = public university; GROUP = group characteristics.
'ne' indicates no effect; '+' indicates positive effects; '-' indicates negative effects; and 'yes' indicates that there is an impact, and it depends on what we control for.
[a]This effect is controlled using different approaches.
[b]In this case, the authors test whether (or not) a private university affects TTO performance.

Table 2: Descriptive statistics by university categories

University category	Statistics	ETP	PUB	PAT_APP	SW_APP	PAT_EXT	Nb_PAT_EXT	ETP	PUB	PAT_APP	SW_APP	PAT_EXT	Nb_PAT_EXT
		2003–2004						2005–2006					
ING	Mean	4.67	1888.33	10.67	0.67	3.33	6.00	6.32	2139.67	12.67	2.33	1.33	1.33
	SD	4.62	723.78	9.50	1.15	4.16	4.00	4.04	787.75	6.51	1.53	2.31	2.31
	Min	2.00	1420.50	1.00	0.00	0.00	2.00	2.00	1615.00	6.00	1.00	0.00	0.00
	Max	10.00	2722.00	20.00	2.00	8.00	10.00	10.00	3045.50	19.00	4.00	4.00	4.00
UPAM	Mean	3.38	1487.08	10.25	1.00	4.42	4.83	5.29	1468.67	6.33	2.42	1.50	1.58
	SD	1.06	647.51	7.94	1.48	4.38	4.43	3.89	647.47	4.16	2.43	1.68	1.62
	Min	1.50	757.50	2.00	0.00	0.00	0.00	1.90	481.00	1.00	0.00	0.00	0.00
	Max	5.00	2849.00	24.00	5.00	12.00	13.00	15.58	2891.50	15.00	7.00	5.00	5.00
UPSM	Mean	1.83	920.00	7.33	1.33	0.67	2.67	3.00	952.17	6.00	1.00	3.33	3.33
	SD	1.04	1181.02	7.51	1.15	1.15	1.15	0.66	1176.28	5.29	1.00	3.51	3.51
	Min	1.00	137.50	3.00	0.00	0.00	2.00	2.25	175.50	2.00	0.00	0.00	0.00
	Max	3.00	2278.50	16.00	2.00	2.00	4.00	3.50	2305.50	12.00	2.00	7.00	7.00
USC	Mean	10.19	6082.13	23.33	3.33	14.83	15.75	13.29	6569.75	18.50	3.67	5.17	6.75
	SD	7.05	3799.23	12.40	5.03	9.24	8.80	7.75	4166.86	14.98	5.09	6.28	5.69
	Min	4.00	2063.00	7.00	0.00	3.00	5.00	3.00	2141.50	2.00	0.00	0.00	0.00
	Max	30.00	15422.00	43.00	17.00	34.00	33.00	34.10	17160.50	52.00	17.00	18.00	18.00

Source: Authors' calculations

Table 3: Descriptive statistics by categories of universities

University category	Variable	N.Obs	Mean	SD	Min	Max
ING		3				
	Hospital		0.00	0.00	0.00	0.00
	Age		18.67	8.50	10.00	27.00
UPAM		12				
	Hospital		0.92	0.29	0.00	1.00
	Age		9.25	2.73	5.00	13.00
UPSM		3				
	Hospital		0.00	0.00	0.00	0.00
	Age		3.33	0.58	3.00	4.00
USC		12				
	Hospital		0.83	0.39	0.00	1.00
	Age		16.08	9.22	3.00	36.00

Sources: Bach and Llerena 2006, 2008, 2010.
Notes: Age has been computed starting from 2006.

Table 4: Summary of results for French TTOs between 2003 and 2006 by university category

University category	BC-EC	BC-TC	BC-M
ING-9	1.3281	0.7175**	1.0207
ING-24	0.2943**	0.7821	0.2379**
ING-30	0.9527	0.8656	0.8516**
Geom.Mean-all	0.7194	0.7861	0.5914
Geom.Mean-subset	0.2943	0.7175	0.4501
Improvement	1	1	2
No change	2	2	1
Decline	0	0	0
UPAM-2	1.2904	0.7268	1.0082
UPAM-14	1.1315	0.7629	0.9423**
UPAM-18	0.7327**	0.6898**	0.5361**
UPAM-21	1.6565**	0.7277**	1.2763**
UPAM-22	1.0056	0.8924	0.9226
UPMA-23	1.5123	0.7959	1.2790**
UPAM-31	4.4114**	0.7292**	3.4756**
UPAM-41	4.5513**	0.8139	3.8962**
UPAM-43	0.3351**	0.7727	0.2722**
UPAM-50	0.8461	0.7331**	0.6522**
UPAM-55	0.4265**	0.7326**	0.3311**
UPAM-59	1.5880**	0.7943	1.3007
Geom.Mean-all	1.2154	0.7626	0.9810
Geom.Mean-subset	1.2768	0.7223	0.9543
Improvement	3	5	5
No change	5	7	3
Decline	4	0	4
UPSM-4	1.0489	0.7265	0.8556**
UPSM-17	0.8756	0.4994**	0.5514**
UPSM-25	1.0300	0.7068	0.8123**
Geom.Mean-all	0.9816	0.6353	0.7264
Geom.Mean-subset	0.0000	0.4994	0.7264
Improvement	0	1	3
No change	3	2	0
Decline	0	0	0
USC-5	2.5271**	0.7747	2.0241**
USC-13	4.8508**	0.8372	4.2390**
USC-26	0.7150**	0.7557	0.5831**
USC-33	0.8142	0.8600	0.7225**
USC-37	1.6344**	0.7292	1.2669**
USC-42	2.9344**	0.8190	2.5498**
USC-51	1.4774	0.7472	1.1800**
USC-64	1.6225	0.7357	1.2582
USC-65	0.6975**	0.8080	0.5855**
USC-68	0.7412**	0.8866	0.6809**
USC-69	0.9304	0.7280	0.7192**
USC-73	0.5659**	0.7673	0.4598**

University category	BC-EC	BC-TC	BC-M
Geom.Mean-all	1.2954	0.7857	1.0713
Geom.Mean-subset	1.3684	0.7747	1.0558
Improvement	4	0	6
No change	4	12	1
Decline	4	0	5
Geom.Mean-all	1.1581	0.7601	0.9374
Geom.Mean-subset	1.2060	0.6846	0.9092
Improvement	8	7	16
No change	14	23	5
Decline	8	0	9

Notes: EC = Efficiency Change, TC = Technical Change, M = Malmquist Index, BC- = Bias-Corrected. ** Statistically significant at 5%. Geom.Mean-all is calculated as the mean of changes associated with the entire sample, whereas Geom.Mean-subset is calculated as the mean of only statistically significant changes. Improvement, No change and Decline indicate the number of TTOs which experienced statistically significant progress, any significant change and statistically significant regress, respectively.

Table 5: Summary of results for French TTOs between 2003 and 2006 depending on the presence of a hospital

Hospital	University category	BC-EC	BC-TC	BC-M
Yes	UPAM-2	1.2904	0.7268	1.0082
Yes	USC-5	2.5271**	0.7747**	2.0241**
Yes	USC-13	4.8508**	0.8372	4.2390**
Yes	UPAM-14	1.1315	0.7629	0.9423**
Yes	UPAM-18	0.7327**	0.6898**	0.5361**
Yes	UPAM-21	1.6565**	0.7277**	1.2763**
Yes	UPAM-23	1.5123	0.7959	1.2790**
Yes	USC-26	0.7150**	0.7557	0.5831**
Yes	UPAM-31	4.4114**	0.7292**	3.4756**
Yes	USC-37	1.6344**	0.7292	1.2669**
Yes	UPAM-41	4.5513**	0.8139	3.8962**
Yes	USC-42	2.9344**	0.819	2.5498**
Yes	UPAM-43	0.3351**	0.7727	0.2722**
Yes	UPAM-50	0.8461	0.7331**	0.6522**
Yes	UPAM-55	0.4265**	0.7326**	0.3311**
Yes	UPAM-59	1.5880**	0.7943	1.3007
Yes	USC-64	1.6225	0.7357	1.2582
Yes	USC-65	0.6975**	0.808	0.5855**
Yes	USC-68	0.7412**	0.8866	0.6809**
Yes	USC-69	0.9304	0.728	0.7192**
Yes	USC-73	0.5659**	0.7673	0.4598**
Geom.Mean-all		1.2844	0.7663	1.0406
Geom.Mean-subset		1.3249	0.7308	1.0188
Improvement		7	6	10
No change		6	15	3
Decline		8	0	8
No	UPSM-4	1.0489	0.7265	0.8556**
No	ING-9	1.3281	0.7175**	1.0207
No	UPSM-17	0.8756	0.4994**	0.5514**
No	UPAM-22	1.0056	0.8924	0.9226
No	ING-24	0.2943**	0.7821	0.2379**
No	UPSM-25	1.03	0.7068	0.8123**
No	ING-30	0.9527	0.8656	0.8516**
No	USC-33	0.8142	0.86	0.7225**
No	USC-51	1.4774	0.7472	1.1800**
Geom.Mean-all		0.9095	0.7459	0.7347
Geom.Mean-subset		0.2943	0.5986	0.6785
Improvement		0	2	6
No change		8	7	2
Decline		1	0	1

Table 6: Summary of results for French TTOs between 2003 and 2006 by age

Young TTO	University category	BC-EC	BC-TC	BC-M
Yes	UPSM-4	1.0489	0.7265	0.8556**
Yes	USC-13	4.8508**	0.8372	4.2390**
Yes	UPSM-17	0.8756	0.4994**	0.5514**
Yes	UPAM-22	1.0056	0.8924	0.9226
Yes	UPAM-23	1.5123	0.7959	1.2790**
Yes	UPSM-25	1.0300	0.7068	0.8123**
Yes	UPAM-31	4.4114**	0.7292**	3.4756**
Yes	USC-37	1.6344**	0.7292	1.2669**
Yes	UPAM-41	4.5513**	0.8139	3.8962**
Yes	USC-73	0.5659**	0.7673	0.4598**
Geom.Mean-all		1.6265	0.7421	1.3121
Geom.Mean-subset		2.4599	0.6035	1.3644
Improvement		1	2	4
No change		5	8	1
Decline		4	0	5
No	UPAM-2	1.2904	0.7268	1.0082
No	USC-5	2.5271**	0.7747	2.0241**
No	ING-9	1.3281	0.7175**	1.0207
No	UPAM-14	1.1315	0.7629	0.9423**
No	UPAM-18	0.7327**	0.6898**	0.5361**
No	UPAM-21	1.6565**	0.7277**	1.2763**
No	ING-24	0.2943**	0.7821	0.2379**
No	USC-26	0.7150**	0.7557	0.5831**
No	ING-30	0.9527	0.8656	0.8516**
No	USC-33	0.8142	0.8600	0.7225**
No	USC-42	2.9344**	0.8190	2.5498**
No	UPAM-43	0.3351**	0.7727	0.2722**
No	UPAM-50	0.8461	0.7331**	0.6522**
No	USC-51	1.4774	0.7472	1.1800**
No	UPAM-55	0.4265**	0.7326**	0.3311**
No	UPAM-59	1.5880**	0.7943	1.3007
No	USC-64	1.6225	0.7357	1.2582
No	USC-65	0.6975**	0.8080	0.5855**
No	USC-68	0.7412**	0.8866	0.6809**
No	USC-69	0.9304	0.7280	0.7192**
Geom.Mean-all		0.9772	0.7693	0.7924
Geom.Mean-subset		0.8722	0.7200	0.7236
Improvement		7	5	12
No change		9	15	4
Decline		4	0	4

Figures

Fig. 1: Boxplot of TTOs' efficiency changes, technological changes and Malmquist Index by university category and presence of a hospital. TTOs without hospitals are represented in blue and TTOs with hospitals in green

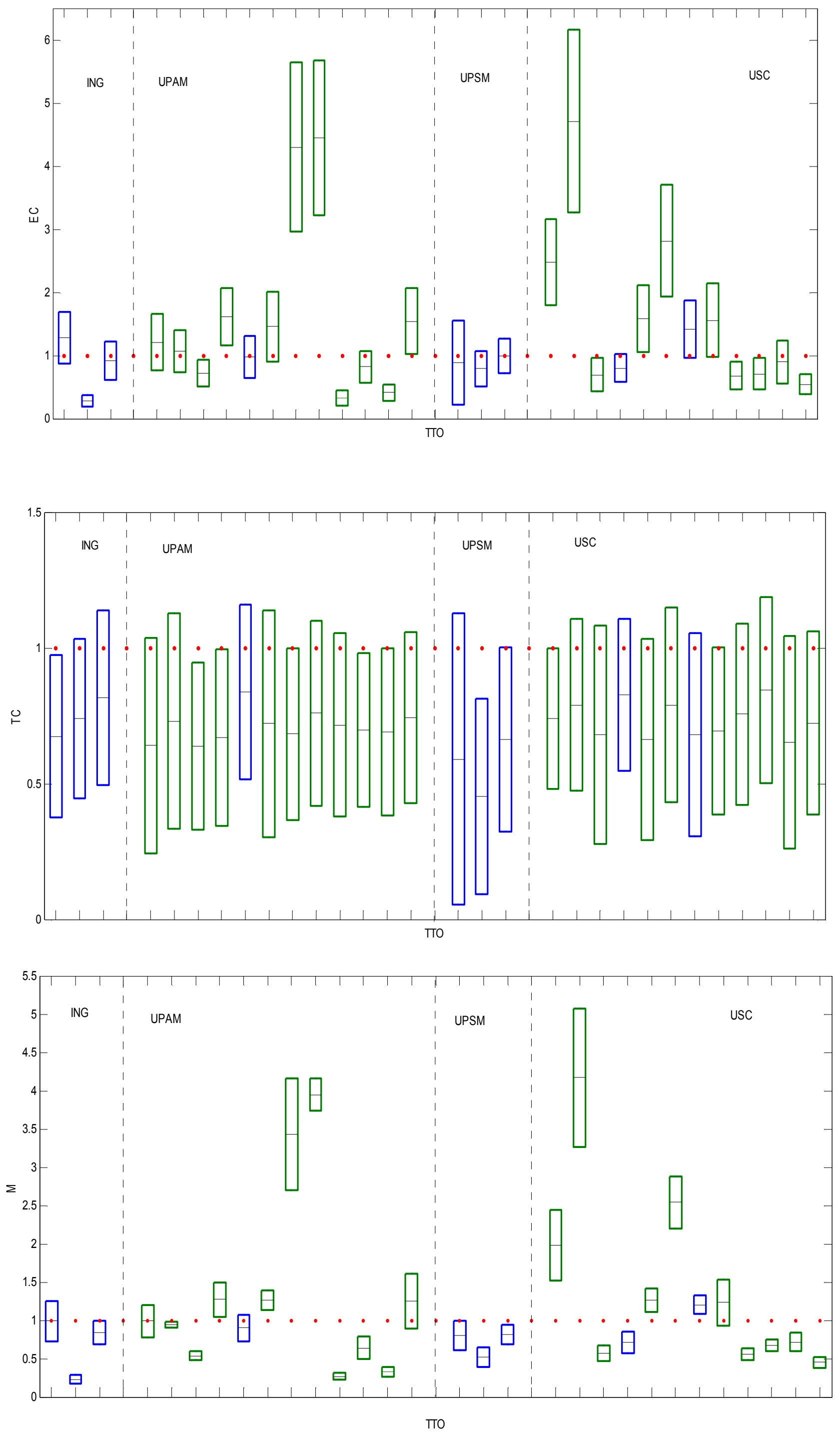

Fig. 2: Boxplot of TTOs' efficiency changes, technological changes and Malmquist Index by university category and seniority. Mature TTOs are represented in blue and young TTOs in green