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## The relationship among innovative output, productivity, and profitability: a test comparing USPTO and EPO data

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# JENA ECONOMIC RESEARCH PAPERS



# 2007 – 020

## **The Relationship among innovative Output, Productivity, and Profitability. A test comparing USPTO and EPO data**

by

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# **THE RELATIONSHIP AMONG INNOVATIVE OUTPUT, PRODUCTIVITY, AND PROFITABILITY. A test comparing USPTO and EPO data\***

June 2007

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## **Abstract**

The aim of this paper is to test whether patent-based indicators are still reliable measures of innovativeness in light of organizational changes in the field of Intellectual Property Rights (IPR) protection and the regulatory reforms already under way respectively at the U.S. Patent and Trademark Office (USPTO) and the European Patent Office (EPO). For most high-tech industries, patents represent an outcome of the production process and their number can be taken as a proxy for a firm's ability to improve its productivity growth and profitability. The case study reported here concerns the biotechnology industry in Italy, whose firms, by definition, have Intellectual Property (IP) activities in their portfolios. For this purpose, we use a unique data set which collects balance sheet items and patent information from EPO and USPTO. After linking firms' financial and production data with the patent information, we estimate a modified knowledge production function in which the dependent variable is alternatively (labor) productivity growth and profitability. Our findings show that only patents with the EPO, along with larger firm size, have a statistically significant relationship with productivity growth and profitability. This suggests that firms pursue different strategies when patenting with the USPTO and the EPO, and that this difference reflects statutory changes made to the former during the relevant period.

JEL-classification: L25; L65; O34

Keywords: IP Protection; Productivity; Profitability;  
Biotechnology Industry; Italy

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## 1. Introduction

According to the normative theory of property institutions, it is the government that enhances property rights. However, as Yoram Barzel (1989, p. 65) observed, the fact that economic agents acquire and maintain property rights is, following a positive view of rights as a response to economic conditions, a matter of choice: individuals choose to exercise rights only when and if they believe that the gains from doing so will exceed the costs. The design, implementation, and protection of Intellectual Property Rights (IPR) is a typical case to which Barzel's positive view applies.

This paper explores the relationship between the IPR strategy chosen by firms in high-tech industries and their characteristics, productivity performance, and profitability. In particular, it provides a close-up portrait of innovation activities carried out by Italian firms in the biotechnology aggregate, doing so with the aid of highly detailed patent data drawn from all patents granted in the U.S. (source: USPTO, United States Patent and Trademark Office) and in Europe (source: EPO, European Patent Office) to inventors in this patent class.

The traditional approach based on the knowledge-production function originally put forward by Griliches (1979) focuses on the allegedly linear relationship between new technological knowledge generated by R&D and patented inventions as inputs affecting, along with an intangible "stock of knowledge" measured by past R&D and its results, productivity performance, and ultimately the market value of the firm. In this paper, we take a somewhat different perspective, investigating the effects exerted by both innovative output and a set of firm-specific characteristics on the performance of the (small) population of incorporated and unincorporated businesses in the Italian biotechnology industry. In particular, we compare the impact of patents lodged with EPO and USPTO respectively on (labor) productivity growth and firm profitability. We expect patents to explain a large portion of productivity growth. Moreover, we believe that patent data enables comparison of the effectiveness and the technological and economic value of patents granted by different institutions with different patterns of behavior and organizational characteristics: the USPTO and the EPO. In terms of IPR strategy, one might therefore argue that inventors decide whether to apply to one or the other patent office after comparing the expected productivity and profitability gains from the invention against the total costs of patenting with the given institution. The underlying rationale is that, consistently with Jaffe and Lerner (2004), patenting with these two institutions may have been driven by different motivations over the last two decades, following the profound changes that occurred in the U.S. patent system after the introduction of the Court of Appeals for the Federal Circuit (CSFC) in 1982 and the transformation of the USPTO into a private

agency in 1990. We accordingly intend to test the idea put forward by these authors that the dramatic increase in the number of patents granted in the United States after 1982 has been accompanied by a proliferation of patent awards of dubious merit, and which, for this reason, do not have much to do with improving a firm's productivity performance. Accordingly, the present study conducts an indirect test of Jaffe and Lerner's hypothesis that "the institutional changes of the last two decades have altered the incentives of inventors, firms, and the patent office in ways that encourage legal maneuvering and discourage innovation" (p. 18).

Based on a panel of 58 firms in the Italian biotechnology industry during the 1990s, our regressions show that the contribution of innovative output to productivity growth is positive and statistically significant only when EPO patents are taken into account, whereas patenting with the USPTO results in slower productivity growth. We also present evidence that a larger firm size (total assets) exerts a positive impact on productivity growth, with a non-linear, (quadratic) relationship between the two variables. As for profitability, our findings are consistent with those obtained for productivity: more patents with the EPO result in higher values of the Return on Equity (ROE) index, whereas the opposite proves true for the USPTO patents. Finally, the relationship between firm size and profitability is also positive but curvilinear.

The paper is organized as follows. Section 2 discusses the role of patent-based indicators as reliable measures of innovativeness in light of recent organizational changes in the field of IP protection and the regulatory reforms under way respectively at the USPTO and the EPO. Section 3 discusses the unique dataset developed for the purposes of this paper, while Section 4 comments on the econometric estimates. Finally, Section 5 draws some concluding remarks.

## **2. Patent-based indicators: are they *still* reliable?**

The institutions typically involved in IP protection are international bodies for the setting of standards (such as WIPO, the World Intellectual Property Organization, and WTO, the World Trade Organization), national governments transposing supra-national norms and rules, and the national patent offices implementing those norms and rules. Although formally in charge of designing the norms and rules in operation within their territory, national governments are losing ground to international bodies and multilateral agreements setting the standards. Since 1995, WTO has exercised enforcement power in relation to fulfillment by the member states of the minimum IP protection standards set by the 1994 TRIPS (Trade-Related Aspects of Intellectual Property Rights) agreement signed in Marrakesh (Morocco) to establish the rules concerning intellectual property

rights in issues related to international trade. This agreement was designed to equip the owners of Intellectual Property Rights (IPR) with the enforcement mechanisms necessary to combat piracy effectively, and to reduce the losses that they may incur in countries unable to provide full IPR protection. In particular, the minimum standards set by the TRIPS agreement are related to the maximum length of a patent; and they provide that patents should be available and patent rights enjoyable without discrimination as to the place of invention, the field of technology, and whether products are imported or locally produced.<sup>1</sup>

As a consequence of the above and related changes in the regulatory framework, patents have become the most powerful instruments of IPR protection: over the 1992-2002 period the number of patent applications submitted in Europe, United States and Japan increased by more than 40% (OECD, 2004), this being also due to the emergence of new and rapidly growing technological fields such as Information and Communication Technologies (ICT) and biotechnologies. To keep pace with these technological advances, the IPR protection systems of industrialized countries have undergone (or are still undergoing) dramatic changes, most them intended to strengthen the rights and prerogatives of patent holders.

When an inventor – an individual, a firm, a public institution, or a university – decides to protect the results of their inventive activity, the standard procedure is to apply for patent protection with the national patent office. However, there are still significant differences across countries in how patent offices and their procedures are regulated. These differences involve all aspects of patenting – application, fees, the average length of the granting procedure, renewals, and so on – likely to affect the choice among the various offices. For correct use to be made of patent statistics, therefore, it is advisable to be aware of these differences and peculiarities.

The first crucial issue concerns the *priority date*, that is, the date on which the first application has been submitted, regardless of where the submission has been made. In fact, on the one hand the priority date identifies the beginning of the overall procedure, whereas on the other it is the date closest to the actual time of the invention's creation. Within the EPO regulatory framework, it is made public 18 months after submission of the application, whereas the USPTO discloses it only after the patent has been granted. In both systems, the maximum patent length is twenty years from submission of the application, with renewal fees that must be paid annually in order to maintain the patent protection.

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<sup>1</sup> The harmonization of standards consequent upon the TRIPS agreement has been particularly problematic for developing countries, which have been forced to undertake major reform of their legislation on intellectual property in such crucial fields as pharmaceuticals and food (McCalman, 2001).

Since EPO and USPTO are the most important patent offices to which inventors submit applications for IPR protection, the next two subsections focus on certain features specific to each of these two institutions.

### *2.1. European Patent Office*

EPO was created in 1978 to promote infra-European cooperation in the field of IPR protection through a centralized procedure and the acceptance of common rules by the countries that had previously signed the Munich 1973 European Patent Convention (EPC). An EPO patent grants IPR protection potentially enforceable in all the countries that have adhered, at various times, to the EPC. This has significantly reduced the bureaucratic procedures to be followed in applying for patent protection, and it has pushed down the costs of extending patent protection in different and several countries.<sup>2</sup> The harmonization process therefore concludes once the patent has been granted, because all the legal implications of patent enforcement still differ among countries. This results in different standards in different countries, and it impedes both the adoption of a common approach to disputes involving patents and the introduction of the so-called “Community patent”, as a pillar around which to redesign the entire patent system within the EU. As a step in this direction, at the end of 2003 a European Patent Litigation Agreement (EPLA) was signed to create the bases for introduction of a centralized European Patent Court of Appeal (EPCA) which would hear appeals on patent cases with respect to any infringement concerning the community patent.

### *2.2. U.S. Patent and Trademark Office*

While the E.U. has pursued the community patent and discussed the creation of a centralized appellate court, in the U.S. the 1982 Federal Court Improvements Act introduced the Court of Appeals for the Federal Circuit (CAFC). This replaced the twelve ‘circuit’ courts which had previously adjudicated all formal disputes involving patents. The main reason for dissatisfaction with the old patent opposition system was the tendency of different federal circuits to issue conflicting or inconsistent decisions, which then had to be settled by the U.S. Supreme Court. However, when the Supreme Court was not asked, or did not want, to decide on conflicting interpretations in different circuits, as the results of divergent standards in different courts, there ensued a “undignified race of patent applicants and alleged infringers [competing] to have their cases heard in a circuit that would be sympathetic to their views” (Jaffe and Lerner, 2004, p. 100).

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<sup>2</sup> The creation of EPO represented a true change of regime in Europe. Deng (2007) has found that the average quality and the private value of the OPO patents during the early 1980s were substantially higher than those obtained through the national offices in Germany, France and the UK.

Introduction of a specialized court was thus seen as a way to give consistency to the volatile area of patent litigation and to alleviate the burden on the appellate courts.

The results of the creation of the CAFC have nevertheless been highly controversial. As Jaffe and Lerner (2004, p. 104) observe, “whereas the circuit courts had affirmed 62 percent of district court findings of patent infringement in the three decades before the creation of the CAFC, the CAFC in its first eight years affirmed 90 percent of such decisions” (see also Jaffe, 2000; Hall and Ziedonis, 2001; Jaffe and Trajtenberg, 2002)

The second major change in the organization of patenting in the US came in 1990, when the Congress decided to convert the USPTO into a service agency whose costs would be covered by the fees paid by patent applicants, who thus became its clients. The main reason for the decision to change the USPTO’s financing structure was the need to reduce the overall costs of the patent system. Unfortunately, it also affected the patent examiners’ attitude towards patent applicants (their ‘clients’), leading to a loss of selectivity which hugely increased the number of patents issued, most often with only minimal review.

The statutory changes of the past two decades in the U.S. have brought about the so-called “pro patent era”, in which a strengthening of patent rights combined with a weakening of the standards for the granting of patents has resulted in an unprecedented proliferation of patents, most of them relative to existing technologies. One of the industries characterized by cumulative and overlapping innovations is biotechnology, where many patents concern the extraction and manipulation of genetic material.

In light of the radical changes that have already occurred in the American patent system but are still ineffective or only under way in Europe, it is interesting to test whether the procedures of USPTO and EPO are now so different that they produce marked differences in the technological and economic value of patents granted by each of the two institutions to the same firms for the same inventions. Study of the impact of the innovative output of Italian biotechnology firms, as it results from the EPO and USPTO patents, on the dynamics of productivity and profitability may serve this purpose well.

### *2.3. The reliability of patent-based indicators*

Owing to their nature as government-granted rights to prevent other parties from making, selling, or using an invented product or process, patents represent incentive mechanisms in which the reward is linked to the social value of the invention (Scotchmer, 2004). Thus, firms preferably patent those inventions from which they are convinced they will be able to extract the highest



reward. For this reason, patents are a quantitative and rather direct measure of invention (Pakes and Griliches, 1984).

Indeed, for at least four decades,<sup>3</sup> patent counts as measures of innovation have enjoyed great popularity among applied economists, who use them to estimate the technological strength and competitiveness of countries, industries, and firms. In particular, usually employed for the purposes of international comparisons are indicators based on the information contained in the files of the USPTO, given that the U.S. is the largest and most important technological market in the world, and, more recently of the EPO. In what follows we test whether these sources still provide consistent profiles of the innovative performance of firms, focusing on a sample of Italian firms in a high-tech industry like biotechnology. The assumption underlying our analysis is that the significant statutory changes which have occurred in the USPTO but not (yet) in the EPO may have induced European (Italian) firms active in the relatively new field of biotechnology to take EPO as the preferred agency for their most promising inventions, while they use the USPTO to pursue a pre-emptive strategy involving pseudo-inventions or inventions with relatively less technological content. If this assumption is confirmed by the empirical analysis, we will be able to argue that the two most important sources of information on the inventive process provide different, if not contrasting, pictures of the process investigated.

In this respect, our paper is a contribution to the long-standing tradition of studies using alternative indicators and methodologies to adjust for variation in the quality of patent-based measures.

In the field of non-patent-based indicators, an announcement of a newly-developed product or process in trade journals is likely to be the most reliable of such indicators because it shows whether the conception of the new product or process is actually starting to acquire economic value. Acs and Audretsch (1987, 1988) were among the first to use this indicator. They employed a database released by the U.S. Small Business Administration to analyze the impact of firm size on industry's innovativeness. In Europe, Kleinknecht and Bain (1993) coordinated a project aimed at developing the same indicator for a group of countries including Austria, Ireland, the Netherlands, and the UK. Likewise, Piergiovanni and Santarelli (1996) built a unique database (PRODIN89) comprising all the product innovations reported in the complete 1989 volume of a sample of 25 Italian technical and trade journals. Coherently with the findings by Acs and Audretsch, most of these subsequent studies highlighted the significant presence of small firms in innovation.

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<sup>3</sup> That is, since when Jacob Schmookler (1966) started to make systematic use of the information contained in the patent records collected at the PTO – compiling a number of time series of patent totals by industry, going back more than a century - to identify a positive and significant correlation between the dynamics of the overall process of innovation and economic growth.

As regards indicators adjusting for variation in the quality of patents, Schankerman and Pakes (1986) were the first to use information on patent renewal to estimate the value of patent rights, discovering that patent quality at the country level accounted for the largest portion of the observed decline in the average number of patents per scientist and engineer. More recent studies (most of which are collected in Jaffe and Trajtenberg, 2002) have instead refined the use of the number of patent citations, while others have used the number of countries in which a patent has been taken out (patent family size) (Putnam, 1996) or the number of claims in the patent application (Tong and Frame, 1994; ) as proxies for patent quality. Lanjouw and Schankerman (2004) combine some of these criteria to develop a composite index of patent quality which takes account of both the technological and value dimensions of an innovation, including the number of claims, backward and forward citations in and to the patent, and family size.

### 3. Data and methodology

#### 3.1. Data

The biotech industry is a relatively young one: the first European patent in the field was granted in 1980, so that the patent wave is fully included in both the EPO and the USPTO databases. Moreover, the industry is usually considered to be an example of how the proliferation of patents in a certain field can be connected to increasing confusion and legal uncertainty due to the features of the entire inventive process in the same field. One cannot avoid mentioning, from this perspective, the debate on protecting biodiversity and the importance of traditional knowledge as a source of ‘pseudo-inventions’, with many commentators claiming that the observed explosion in biotech patent applications and grants in the US can be explained by the fact that companies have received patents for trivial or non-existent inventions in this field (see, for example, Kohr, 2002).

Given that biotechnology is a field in which the two fundamental sources of heterogeneity represented by “basicness” and “appropriability”<sup>4</sup> typically apply, because of the scarcity of internationally comparable data on biotechnology R&D in OECD countries, the OECD has developed a provisional statistical definition of biotechnology: “The application of science and technology to living organisms as well as parts, products and models thereof, to alter living or non-living materials for the production of knowledge, goods and services.” The OECD has then identified biotechnology patents as those comprised in a selected list of codified categories in the

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<sup>4</sup> According to Trajtenberg *et al.* (1997), “basicness” refers to originality, closeness to science and breadth of innovations, whereas “appropriability” to the ability of inventors to reap the benefits from their own innovations.

International Patent Classification (IPC).<sup>5</sup> Also due to the low endowment of national technological capabilities, the biotechnology industry is still very small in Italy (see Archibugi and Coco, 2005; Orsenigo, 2001). To develop our database we therefore took all the patents issued by both EPO and USPTO to Italian firms in those categories.<sup>6</sup> Focusing on “core” biotechnology firms, i.e. on firms having less than 500 employees and with their sales almost exclusively in biotechnology, selected from those affiliated with the National Association for the Development of Biotechnologies (Assobiotec, as of December 2005), we therefore identified 58 firms which exhibited a mixed strategy as far as their preference for either USPTO or EPO as an outlet for their patents was concerned. Our sample was highly representative of the overall industry in the country: given that in 2004, according to OECD (2006), a total of 172 “core” biotechnology firms were in operation in the country, it comprised 33% of the entire population.

At first sight (Table 1), firms patented more with the USPTO, although 243 out of 757 inventions were patented with both institutions. In particular, by far the largest portion of biotech patents (61 out of 88, corresponding to 69.3%) by firms in our sample were lodged with the USPTO, whereas if one looks at total patents, the proportion of those with the USPTO declines to 60.1%, thereby confirming the importance of mutual understanding of new knowledge in the biotech itself and the, e.g., pharmaceutical aggregate for innovation in this industry (see Nooteboom, 2000; Wuyts *et al.*, 2005; Nesta and Saviotti, 2006).

Table 1 – Sample firms: number of patents with EPO, USPTO, or both (by field) (1993-2003)

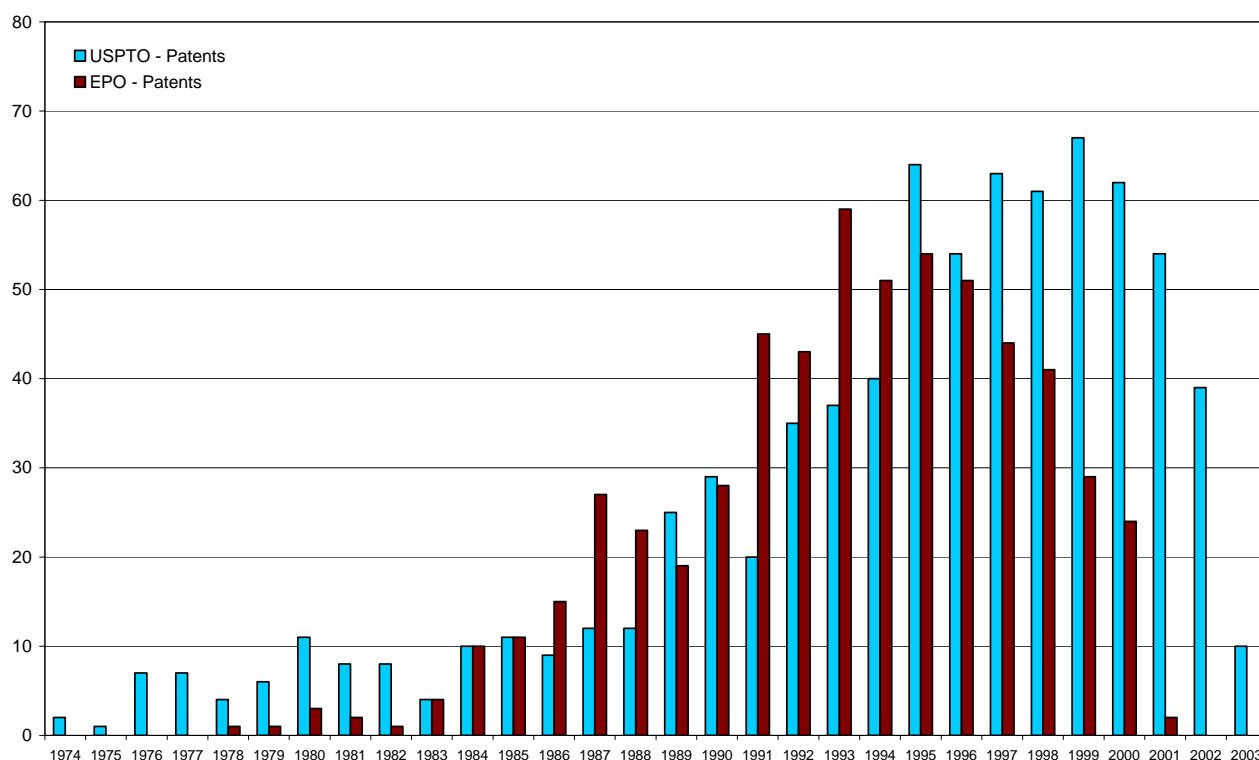
year	PATENTS	EPO PATENTS	USPTO PATENTS	TWIN PATENTS	BIO PATENTS	EPO BIO PATENTS	USPTO BIO PATENTS
1993	92	50	42	20	9	4	5
1994	111	54	57	22	17	10	7
1995	118	51	67	36	15	4	11
1996	103	46	57	31	8	2	6
1997	105	39	66	37	12	4	8
1998	86	29	57	33	18	1	17
1999	87	26	61	23	6	1	5
2000	29	1	28	17	1	0	1
2001	16	1	15	13	2	1	1
2002	9	0	9	9	0	0	0
2003	1	0	1	2	0	0	0
Total	757	297	460	243	88	27	61

<sup>5</sup> The IPC codes selected by the OECD are the following: A01H 1/00 + A01H 4/00 + A61K 38/00 + A61K 39/00 + A61K 48/00 + C02F 3/34 + C07G 11/00 + C07G 13/00 + C07G 15/00 + C07K 4/00 + C07K 14/00 + C07K 16/00 + C07K 17/00 + C07K 19/00 + C12M + C12N + C12P + C12Q + C12S + G01N 27/327 + G01N 33/53 + G01N 33/54 + G01N 33/55 + G01N 33/57 + G01N 33/68 + G01N 33/74 + G01N 33/76 + G01N 33/78 + G01N 33/88 + G01N 33/92.

Of course, this may simply be indicative of a preference among Italian firms for the USPTO, given that it is cheaper to apply to that Office than to the EPO, and given that, according to Jaffe and Lerner (2004) it is also more likely that a patent will be granted by USPTO than by EPO.

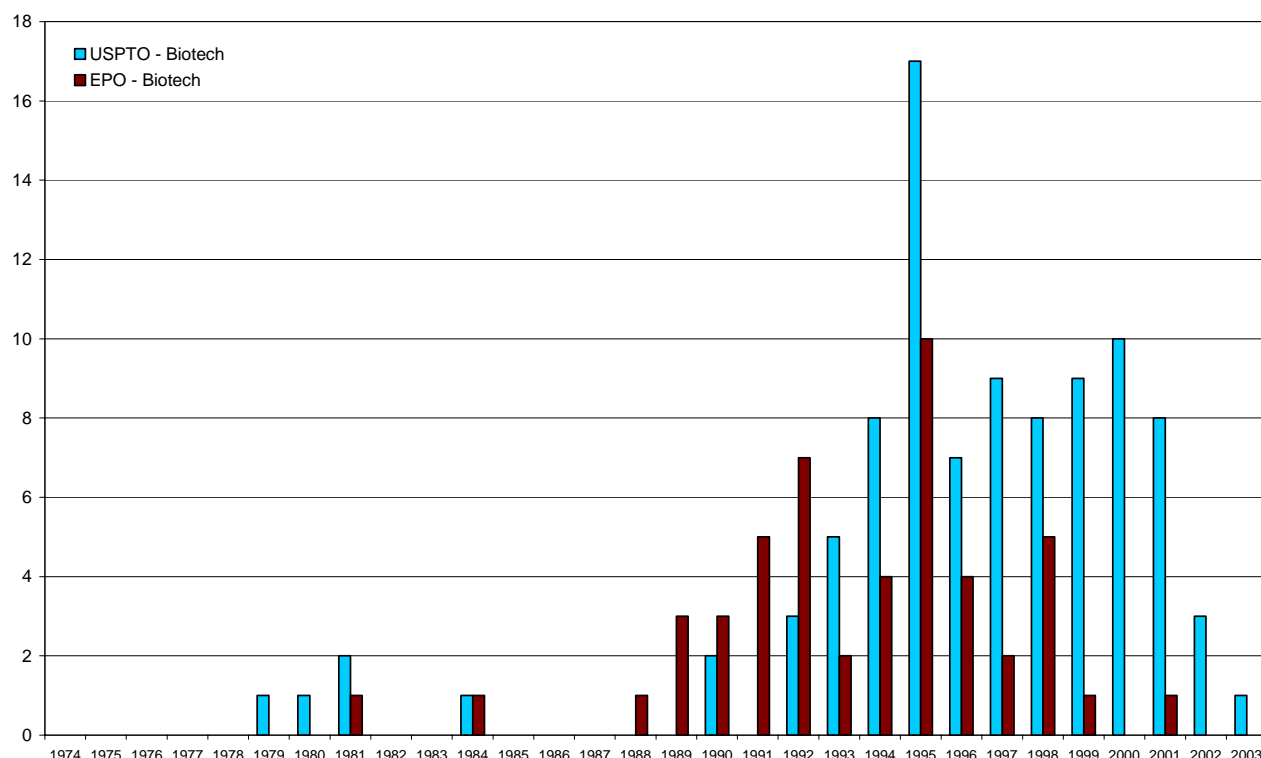
Inspection of the distributions of total and biotech patents with USPTO and EPO respectively (Figures 1 and 2) shows that in both cases a cluster of new EPO patents started to emerge immediately after 1990, whereas a cluster of USPTO patents emerged only after 1995, being matched by a decline in EPO ones. This finding is again indicative that, after the initial wave of new patents, once the Italian firms in our sample discovered that it was cheaper and easier to patent in the United States rather than in Europe, they turned to USPTO for IPR protection. Of course, this evidence has no straightforward implications regarding the relationship between the intrinsic quality of patents with either EPO or USPTO and the productivity and profitability performances of the firms holding the patents. Nevertheless, it does indicate that firms do not consider EPO and USPTO to be perfect substitutes.

Figure 1 – Sample firms: distributions of patents (total) with USPTO and EPO (1974-1003)



<sup>6</sup> To be noted is that, according to OECD (2006), Italy is a country non-specialized in biotechnology patents, given that its share of biotechnology (EPO) patents divided by its share of patents in all technology areas is less than 1.

Figure 2 – Sample firms: distributions of patents (biotech) with USPTO and EPO (1979-2003)



### 3.2. Methodology

In order to determine whether there is a significant relationship between patenting with either one or the other patent office, we simply regressed firms' performance indicators (productivity growth and profitability) on a set of explanatory variables encompassing patenting strategies and firms' characteristics.

Earlier studies (for a survey see Mairesse and Sassenou, 1991; cf. also Griffith *et al.*, 2006) have shown that the productivity growth/innovative output relationship varies over the size distribution of firms, in particular in industries such as the biotechnology sector examined by this paper, at the early stages of their life cycle. However, some authors (e.g. Duguet, 2006) have found that, in general, radical innovations are the most and only significant contributors to productivity growth.

Motivated by these findings, this paper explores the relation among productivity growth, profitability, innovation and firm size by estimating two simple OLS regressions with the appropriate robustness checks. We start by specifying the following estimating equation for the relationship between labor productivity growth (LPG, computed as the rate of growth of the ratio of value added to employment) in each year over the relevant 1993-2003 period, and a set of

explanatory variables, including the stock of EPO and USPTO patents in the same year, biotech patents with EPO and USPTO in the previous year (bioEPO, bioUSPTO), as well as a proxy (total assets) for firm size in previous year:

$$(1) \text{LPG}_{it} = \alpha_i + \beta \text{StockEPO}_{it} + \chi \text{StockUSPTO}_{it} + \delta \text{bioEPO}_{i,t-1} + \varepsilon \text{bioUSPTO}_{i,t-1} + \zeta \log \text{SIZE}_{i,t-1} + \eta \log \text{SIZE}_{i,t-1}^2 + \upsilon_{it}$$

The first determinant in equation (1) is the total stock of patents with EPO, whilst the second is the total number of patents with USPTO. The additional explanatory variables controlling for firm size (in logs, SIZE, SIZE<sup>2</sup>) in the previous period indicate the extent to which LPG is affected by firm size in either a linear or a non linear manner.

In equation (2) the focus is on profitability, and for this purpose the expected value of the ROE index for each firm in each year is made conditional on the values of the same explanatory variables used in the productivity equation:

$$(2) \text{ROE}_{it} = \alpha_i + \beta \text{StockEPO}_{it} + \chi \text{StockUSPTO}_{it} + \delta \text{bioEPO}_{i,t-1} + \varepsilon \text{bioUSPTO}_{i,t-1} + \zeta \log \text{SIZE}_{i,t-1} + \eta \log \text{SIZE}_{i,t-1}^2 + \upsilon_{it}$$

Both equations (1) and (2) are estimated simply by OLS, on the pooled dataset with time dummies, with robust and clustered standard errors.

#### 4. Empirical results

From a general viewpoint, inspection of the descriptive statistics reported in Table 2 shows that, on average during the relevant period, firms in the sample experienced negative earnings corresponding to a poor return on equity. However, this is typical of New Technology Based Firms (NTBFs), which do not have well-developed managerial structures and have not yet been able fully to exploit the innovative output that they are about to produce. The positive dynamics of labor productivity is instead consistent with the general patterns that have emerged in knowledge-intensive activities over the last decade.

The first noteworthy result from estimation of equation (1) (Table 3) is that, as regards a possible difference in the influence of the firm stock of patents with EPO and USPTO respectively as determinants of productivity growth, only patents with EPO appear to have a significantly positive

impact on the dependent variable. In fact, the coefficient of the StockUSPTO variable has a negative sign and is statistically different from zero. These results suggest that either Italian firms in the biotechnology industry tend to patent in a broader set of technological areas with the USPTO than with the EPO, or that patents with the USPTO are in fact less beneficial in terms of the productivity gains that they produce. Inspection of the impact of biotechnology patents in a strict sense on LPG does not change the overall picture significantly: again, only patents with the EPO result in a positive and statistically significant relationship with productivity growth.

Table 2 – Descriptive statistics

<i>Variable</i>	<i>Mean</i>	<i>Median</i>	<i>Std. Err.</i>
Total assets (ths. of euros)	1506756	69582	211599.5
ROE	-14.753	6.405	149.427
Labor Productivity growth	2.841	.0422	44.010
No. of firms		58	

The last variable taken into account in the OLS regression is firm size in the previous period, as measured by its total assets. The parameter estimates show that larger firm size positively and significantly affects productivity growth; although it does so in a non-linear manner because a quadratic relationship between the two variables emerges. This finding is largely consistent with studies emphasizing that, once a certain threshold has been reached in terms of firm size, the productivity yield from innovative activities starts to fall (see among others, Hausman, Hall and Griliches, 1984; Acs and Audretsch, 1991).

The findings do not change in their significance and implications if one looks at the results from estimation of the profitability equation (Table 4). Again as regards possible differences in the influence of the firm stock of patents with EPO and USPTO respectively as determinants of profitability, only patents with EPO exert a significantly positive impact on the ROE. Analysis of the impact of biotechnology patents in a strict sense on the ROE is consistent with the previous finding: only patents with the EPO result in a positive and statistically significant relationship with profitability levels.

Table 3 – Productivity equations

Dep var. $y(t)$	(1)	(2)	(3)	(4)
Stock pat EPO	.129 ** (0.056)	.134 *** (0.041)	.155 *** (0.058)	.158 *** (0.062)
Stock pat USPTO	-.253 ** (0.105)	-.255 *** (0.097)	-.307 *** (0.102)	-.316 *** (0.099)
Pat bio EPO (t-1)		.375 ** (0.225)	.261 ** (0.152)	0.409 * (0.289)
Pat bio USPTO (t-1)		-.786 ** (0.510)	-.882 ** (0.439)	-0.818 * (0.578)
log SIZE (t-1)			0.487 ** (0.322)	-1.637 ** (0.925)
log SIZE <sup>2</sup> (t-1)				.108 ** (0.065)
Const.	.458 * (0.207)	.968 (1.612)	.411 (1.158)	0.945 (1.296)
N. obs	425	425	425	425
R <sup>2</sup>	0.020	0.051	0.058	0.059

OLS estimates on the pooled sample, including year effects. Robust and clustered standard errors in brackets. \*\*\*, \*\*, \* mean statistically significant at 0.01%, 0.05% and 0.10 respectively

Table 4 – Profitability equations, OLS estimates

Dep var. ROE ( $t$ )	(1)	(2)	(3)	(4)
Stock pat EPO	1.312 *** (0.501)	1.393 *** (0.500)	1.299 *** (0.102)	.998 *** (0.092)
Stock pat USPTO	-.415 ** (0.254)	-.479 ** (0.202)	-.653 ** (0.305)	-.494 *** (0.247)
Pat bio EPO (t-1)		18.887 ** (9.390)	16.416 ** (8.957)	17.457 ** (8.712)
Pat bio USPTO (t-1)		-7.381 ** (3.744)	-7.570 ** (4.113)	-7.226 * (4.101)
log SIZE (t-1)			7.766 ** (2.826)	-9.587 ** (4.654)
log SIZE <sup>2</sup> (t-1)				.955 ** (0.457)
Const.	-7.658 * (4.030)	-13.604 (16.712)	-10.795 ** (4.781)	-8.062 (6.584)
N. obs	425	425	425	425
R <sup>2</sup>	0.019	0.045	0.048	0.051

OLS estimates on the pooled sample, including year effects. Robust and clustered standard errors in brackets. \*\*\*, \*\*, \* mean statistically significant at 0.01%, 0.05% and 0.10 respectively



These results provide indirect but statistically significant evidence that patenting in the US and in Europe may differ according to different innovation strategies pursued by firms in the emerging biotechnology industry.

## 5. Conclusions

The first part of this paper hypothesized that the increase in the number of patents granted in the United States since 1982 has been accompanied by a proliferation of patent awards of dubious merit, and which, for this reason, do not have much to do with firm productivity and profitability performance. This hypothesis has received preliminary, although indirect, support from an econometric analysis carried out on a sample of Italian firms in the biotechnology industry. Although more numerous both in total and in the biotech sub-group, patents with the USPTO are in fact less beneficial in terms of the productivity gains and profitability performance that they produce. This is indicative that Italian firms in this high-tech industry implement their IPR strategy in relation to the gains/costs expected to derive from the decision to patent with one or the other patent office.

Future research should examine (i) the relationship between R&D expenditure and patenting, either with EPO or USPTO, and (ii) the simultaneous impact of both R&D and patenting on productivity growth and profitability performance.

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