Patents, R&D-Performing Sectors, and the Technology Spillover Effect

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Abstract

This study examines the impact of the three main R&D performing sectors, business, higher education, and government, on patent activities in 14 high income OECD countries during the period 1981-2008 using dynamic panel data model. In addition, the paper investigates the international technological spillover between OECD countries under investigation. The findings suggest that only business R&D is found to have a positive and significant contemporaneous impact on patent activities among all other R&D-performing sectors. The elasticity of patent activities with respect to higher education shows a significant response of patenting only to lagged higher education R&D, while the response of patents to both contemporaneous and lagged government R&D is found to be insignificant. In general, the elasticity of patent activities to R&D expenditure is found to be low which means that none of the R&D-performing sectors is efficient enough in increasing the number of patents. Finally, the technology spillover effect shows that countries with higher technology exports rate realize an increase in their patent activities. In addition, the total OECD expenditure on R&D is found to have a positive and significant impact on domestic patent activities.

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Keywords: *patents, R&D, System GMM, technology change, OECD, technology spillover*

JEL classification*: O31, O32, C23*

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1. **Introduction**

Patent activities have been widely used by many researchers as a measure of technological change and are considered as the output of applied research and development research in the knowledge production function framework. As indicated by Suzanne Scotchmer (2006), this function considers R&D expenditure a measure of inventive inputs and patents a measure of inventive output. The knowledge production function was first introduced by Griliches (1979) and implemented by many researchers such as Ariel Pakes and Griliches (1984), Jaffe (1986) and (1989), Hausman, Hall, and Griliches (1984), and Kortum (1997), to mention a few.

The vast majority of these studies are done at the micro (firm) level. For example, using a modified knowledge production function, Jaffe (1989) identifies the extent to which university research spills over into the generation of inventions and innovations by private firms in the U.S. Henderson et al (1998) shows that the relative importance and generality of university patents has fallen at the same time as the sheer number of university patents has increased which had been contributed to the low quality of patents being granted to universities. Nagaoka (2003) estimates the structural and reduced form patent production functions by treating R&D expenditure and patents as endogenous. Nagaoka findings show insignificant relationship between the firm's sales assets, market concentration, and export orientation on one hand and the patent production function. In addition, Stephan, Black, and Gurmu (2007) estimate a knowledge production function for university patenting using an individual effects negative binomial model. Their findings suggest that patent counts relate positively and significantly to the number of faculty, number of PhD students and number of postdocs.

In another trend, Abdih and Joutz (2005), investigate the long run knowledge production function and the relationship between TFP and the knowledge stock using cointegration techniques on time series U.S. data (1953-1997). They found strong intertemporal knowledge spillovers and that the long-run impact of the knowledge stock on TFP is small. Finally, Czarnitzki, Dirk, Kraft, and Thorwarth (2009) use firm level panel data to distinguish between the effect of "R" and the effect of "D" on patents. They find empirical evidence on the different contribution of "research" and "development" to patenting as their result suggests that the research portion in R&D has a greater role in affecting patenting compared to the development portion.

Also, the relationship between distributed lags of R&D and innovations, at the firm level, is discussed in many studies such as, Hall, Griliches, and Hausman (1986), Griliches (1990), Michele Cincer (1997), and Gurmu and Pérez-Sebastián (2008). Their mutual finding is that the strongest relationship is between innovations and current and first lag R&D only.

In this paper, I use macro annual data in a knowledge production function structure to measure the elasticity of patent activities to business R&D, government R&D, and higher education R&D, in 14 high income OECD countries during the period 1981-2008[1]. The study examines the effectiveness of the three sectors mentioned above as R&D-performing sectors on patent applications registered in both the US Patent and Trademark Office (USPTO) and the European Patent Office (EPO), and also on countries share in triadic patents families. The study is interested in testing whether the productivity of R&D performing sectors in producing patents declines as R&D spending increases. In addition, the paper investigates the international technological spillover between OECD countries under investigation

[1] I follow the well-known assumption of the existence of a proportionate relationship between knowledge and patents as discussed by Zvi Griliches (1987).

which is captured in two ways: first, by measuring the impact of the pooled R&D activities and, second, by measuring the impact of the technology balance of payment ratio on patent activities.

The findings suggest that R&D performed by business sector is the most productive among all other R&D-performing sectors in affecting patent activities contemporaneously while the impact of R&D performed by government and higher education is found to be insignificant. The elasticity of patent activities with respect to lagged higher education R&D is found to be positive and significant while the impact of lagged business and government R&D is found to be insignificant. On the other hand, the technology spillover effect between OECD countries under investigation is estimated to be positive and significant, but weak. The rest of the paper is organized as follows: section 2 shows the main R&D sectors in OECD countries, section 3 describes the econometric model, section 4 discusses the empirical results, and section 5 provides concluding observations.

2. R&D-Performing and R&D-Financing Sectors

When studying the impact of research and development activities conducted in a country on its patent activities, it is useful to distinguish between R&D-performing sectors and R&D-financing sectors[2]. This distinction helps us in getting a more precise idea on the effectiveness of each of the main sectors carrying out R&D mentioned above on patent activities as some of these sectors might play a relatively more important role as R&D performing sector but not as R&D-financing, and vice versa. The following figures show the comparison between the three main R&D

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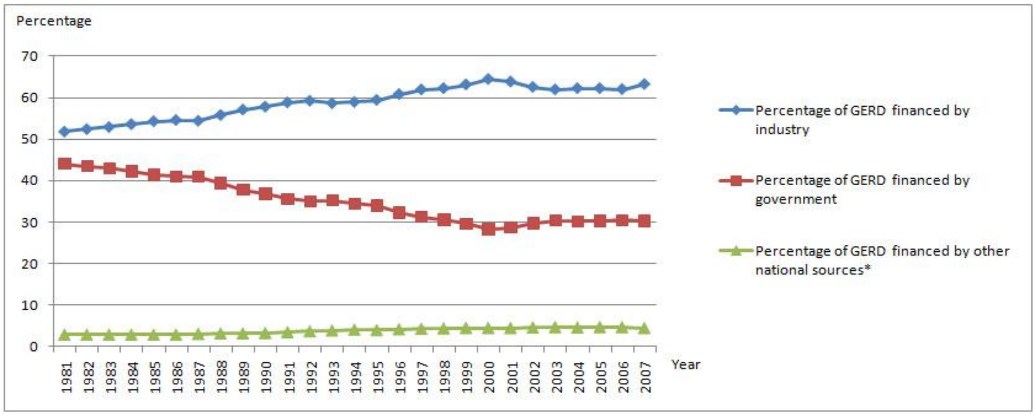
[2] The OECD Main Science and Technology Indicators database (2009) breaks down the R&D effort (performance) into four sectors of performance: business enterprise, higher education, government and private non-profit institutions serving households. In addition, R&D has five sources of financing: the four R&D-performing sectors mentioned above and funds from abroad. This paper focuses on examining the responsiveness of patent activities to R&D performed by the business, higher education, and government sectors as they account for more than 90% of total R&D activities in OECD countries.

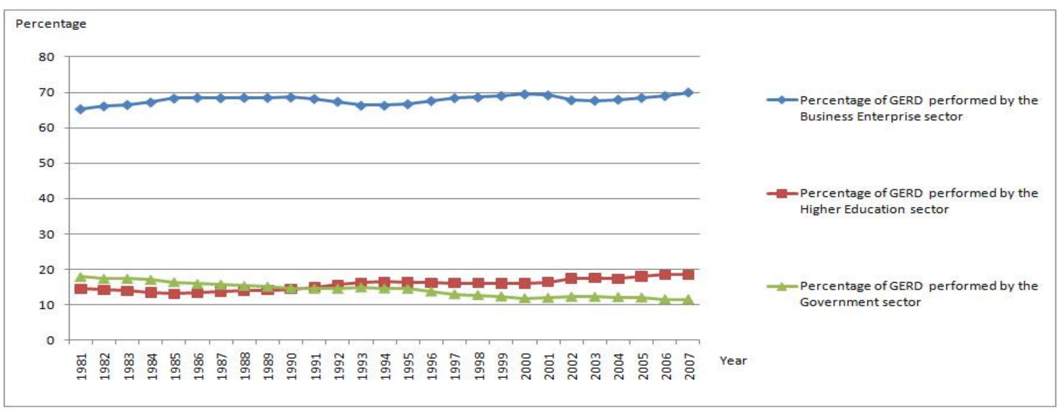
sectors as R&D-performers and R&D-funding sectors in OECD countries over the period 1981-2007.

Figure 1. Gross Expenditure on R&D by Financing Sector (Total OECD)



Source:All percntages in the figure are collected from the OECD Main Science and Technology Indicators Database, 2008.
*This seires includes higher education and private non-profit institutions

Figure 2. Gross Expenditure on R&D by Performing Sector (Total OECD)



Source: All percntages in the figure are collected from the OECD Main Science and Technology Indicators Database, 2008.

Figure 1 shows that the industrial sector plays the dominant role in financing R&D activities followed by government, higher education, and private non-profit institutions. It is also worth to say that the most of industry financed-R&D is directed to business sector enterprises. An indicated by OECD Main Science and Technology Indicators (2009), around 90% of business enterprise expenditure on R&D is financed by the industry. Figure 2 shows that the business enterprise sector plays a leading role as R&D performing sector in the last 2 decades. The OECD Science, Technology, and

Industry Scoreboard (2009) indicates that, although the business enterprise sector remains the main source of R&D funding in most OECD countries (accounting for around two-thirds of the total R&D funding in 2007), its role differs sharply across countries, from over three-quarters in Japan and Luxembourg to less than 35% in Greece and Poland. In addition, the previous 2 figures indicate a continuous decline in R&D financed and performed by the government sector with a gradual rise of the higher education sector as R&D performing sector starting in the early 1990's[3].

The industrial sector also owns the biggest share of patents in all of OECD countries under investigation as indicated in table 1. As noted previously, the paper focuses mainly on measuring the impact of R&D performing sectors as this could be considered as a proxy of the productivity of these sectors compared to measuring the impact of the same sectors as a source of financing R&D.

Table 1. Share of patents owned by industry

Country	**Shares**	
	1995-1997	2003-2005
Spain	44.4%	52.3%
France	62.1	61.9
Canada	67.8	72.9
Italy	68.6	73.5
United Kingdom	74.7	74.8
Denmark	80.8	76.7
Belgium	72.8	77.6
Norway	73.6	79.6
United States	79.2	79.9
Germany	83.1	84.0
Japan	93.2	90.5
Sweden	87.1	92.2
Netherlands	90.3	92.3
Finland	86.7	93.2
European Union	**78.1**	**79.2**
World Total	**78.5**	**79.5**

Note: Patent counts are based on the priority date.
Source: OECD, Patent Database, June 2008

[3] There is a common tendency among most of OECD governments to depend on higher education as R&D performer which could be explained by the increasing credit given to higher education institutions as important partners in building nations.

3. The econometric model

3.1 Methodology

I model the relationship between the three main R&D performing sectors and patent activities in a knowledge production function as articulated by Griliches (1979) where R&D activities serve as the main inputs and patents are the output. The paper aims at estimating the following modified knowledge production function is estimated using a dynamic panel data (DPD) model.

$$P_{it} = \alpha BERD^{\beta 1} GOVRD^{\beta 2} HERD^{\beta 3} \, GGDP^{4} \, TBP^{\beta 5} RDPOOL^{6} \qquad (1)$$

Where P_{it} is patent activities, *BERD* is business enterprise R&D, *HERD* is higher education R&D, *GOVRD* is government R&D, *GGDP* is GDP growth, *TBP* is the technology balance of payments ratio, and *RDPOOL* is the aggregate R&D expenditure in OECD. The last two variables capture the international technological spillover. The technology balance of payments ratio (*TBP*) and is calculated as the ratio of money received by a country to the money paid for the acquisition of patents, licenses, trademarks, and designs:

$$TBP_{it}\, ratio = TBP_{it}(\, receipts) / \, TBP_{it}\, (payments) \qquad (2)$$

A country is considered a net exporter of technology if its *TBP ratio* is greater than 1. A positive impact of the TBP ratio on a country's patents means that technology is originated mainly inside the country (innovative activities) and that technology exports induce patent activities, while a negative impact means that the country depends on importing technology (more payments for the acquisition of patents compared to receipts) to stimulate patent activities.

The second variable that controls for the international technological spillover is the aggregate expenditure on R&D (*RDPOOL*) which is constructed as follows:

$$RDPOOL = \sum_{j=1}^{n-i} GERD_{jt} \qquad (3)$$

Where $GERD_{jt}$ is the gross expenditure on R&D by country *j, n* is the total number of OECD countries in the sample, and *i* is the country under investigation (the country in the left hand side of equation (1)). This is a new way of controlling for the international technological spillover since most of the related studies, such as Coe & Helpman (1995), Caselli & Wilson (2004), and Alvi, Mukherjee, and Eid (2007), used an index of trade openness, manufacturing imports, and FDI as channels though which technology transfers between countries.

The dynamic panel data model is useful since the panel data shows that the time variable (years) is small relative to the cross-sectional variable (countries) after averaging the data to control for business cycle fluctuations (three-year average). In addition, it helps to capture the effect of the convergence variable (lagged patent activities).

The following specification represents a dynamic panel data model that is used in estimating the modified knowledge production function:

$$P_{i,t} = \gamma P_{i,t-1} + \varphi' X_{it} + \sigma' R_{it} + \mu_i + \varepsilon_t + u_{it} \qquad (4)$$

Where *i* represents the unit of observation (countries) and *t* represents time, $P_{i,t}$ is the log of patent activities, $P_{i,t-1}$ is the log of patent activities in the previous period, X_{it} is the vector of the technology spillover and control variables (the technology balance of payments ratio, the aggregate R&D expenditure in OECD, and GDP growth), and R_{it} is the vector of different types of research and development expenditure by performing sector. μ_i is the unobserved individual country-specific effect, ε_t is the unobserved time-specific effect, and μ_{it} captures the effect of the unobserved variables. I use David Roodman's (2006) improved version of the Arellano and Bond's (1991) DPD estimator to implement the Arellano–Bover (1995) and Blundell–Bond (1998) system Generalized Method of Moments (GMM) estimation. The

Arellano–Bover/Blundell–Bond estimator introduces more instruments (lagged levels as well as lagged differences), which can improve the efficiency of the model compared to the original Arellano and Bond (1991) difference GMM estimator. I use the two-step robust estimates of the standard errors in the context of Roodman's version which makes available a finite-sample correction to the two-step covariance matrix derived by Windmeijer (2005). This can make two-step robust more efficient than one-step robust, especially for system GMM. In addition, using this method means that the resulting standard error estimates are consistent in the presence of any pattern of heteroskedasticity and autocorrelation within panel data.

3.2 Data

The OECD sample in this paper contains 14 high-income countries: Belgium, Canada, Denmark, Finland, France, Germany, Italy, Japan, Netherlands, Norway, Portugal, Spain, United Kingdom, and USA. Data is collected mainly from OECD Main Science and Technology Indicators and the World Development Indicators (WDI) databases over the period 1981-2008. Patent data used in this paper are: the number of patents applications registered in the European Patent Office (EPO), the number of patents applications registered in the US Patent & Trademark Office (USPTO), and the countries share in triadic patents families, alternately. Table 2 contains the statistical description of the variables.

Table 2. Statistical Description

Variable	Obs.	Mean	Std. Dev.	Min	Max
Patents (EPO)	126	7.220366	1.971399	0.77319	10.45168
Patents (USPTO)	126	7.570157	2.233818	1.734601	12.31791
Triadic patents families	112	6.512554	10.36797	0.003667	34.89466
Business R&D	126	4.05995	0.243931	3.052979	4.345942
Government R&D	126	2.70454	0.4222	1.59202	3.758021
Higher education R&D	126	3.063054	0.309085	2.212514	3.683247
GDP growth	126	2.500711	1.405831	-2.98999	6.77038
Imports % GDP	126	31.09327	15.07836	7.22081	78.09547
FDI % GDP	126	2.561339	5.765814	-0.16405	60.1201
Aggregate OECD R&D	126	12.74566	0.460768	11.3786	13.3845
TBP ratio	107	16.25657	54.18216	0.039577	323.0707

4. Empirical Results

I estimate equation (4) in three different settings. In each setting a different measure of patent activities is used as mentioned earlier (patent applications registered in USPTO, patent applications registered in EPO, and countries share in triadic patents families). In addition, two different specifications are used in each setting. First, the study considers the traditional international technology spillover variables (country's imports as a percent of GDP and FDI) and, second, the study uses the new international technology spillover variables (technology balance of payments and aggregate R&D expenditure in OECD). Finally, the study estimate equation (4) in a distributed lag model. Table 3 shows the results of estimating the first specification.

Table 3. System GMM estimation of patent elasticity to current R&D

	Dependent variable (Patents registered in EPO)		Dependent variable (Patents registered in USPTO)		Dependent variable (Countries share in triadic patents families)	
Parameter	(1) Values (Robust SE)	(2) Values (Robust SE)	(1) Values (Robust SE)	(2) Values (Robust SE)	(1) Values (Robust SE)	(2) Values (Robust SE)
Lagged dependent variable	0.9 (0.027)***	0.91 (0.025)***	0.96 (0.014)***	0.96 (0.017)***	0.99 (0.013)***	0.98 (0.014)***
BERD	0.5 (0.17)***	0.32 (0.17)**	0.1 (0.06)*	0.26 (0.079)***	0.88 (0.45)**	0.011 (0.5)
GOVERD	0.076 (0.085)	0.038 (0.07)	-0.054 (0.048)	-0.03 (0.047)	-0.13 (0.45)	-0.35 (0.52)
HERD	0.082 (0.12)	-0.04 (0.08)	-0.083 (0.095)	0.04 (0.07)	1.49 (0.38)***	0.26 (0.48)
GGDP	0.036 (0.012)***	0.031 (0.014)**	0.023 (0.01)***	0.011 (0.001)***	0.049 (0.1)	0.03 (0.09)
TBP	0.007 (0.002)***		0.0018 (0.0016)		0.004 (0.0008)***	
RDPOOL	0.035 (0.064)		0.1 (0.05)**		0.69 (0.36)*	
Imports		-0.004 (0.001)***		-0.003 (0.001)***		-0.017 (0.016)
FDI		0.003 (0.003)		0.006 (0.0039)		0.005 (0.0083)
Constant	1.2 (1.2)	-0.42 (0.83)	1.077 (0.7)	-0.62 (0.48)	0.84 (7.1)	0.56 (4.9)

Coefficients are significant at ***1%, **5%, and *10%.

Table 3 shows that lagged patents have the greatest positive and significant effect on the current number of patents in the three settings mentioned above with a point estimate of around 0.9. The impact of GDP growth is found to be positive as expected and significant in the first two settings. Patent elasticity to GDP is estimated to be low as the point estimate ranges from 0.011 to 0.036. Patents' responsiveness to R&D performed by the business sector is significant in all the specifications expect of the last one (where countries share in triadic patents families is the dependent variable and the technology spillover effect is captured by country's imports and FDI).

Patents elasticity to business R&D ranges from 0.1 (in the first specification of the USPTO setting) to 0.88 (in the first specification of the countries share in triadic patents families setting). The low elasticity of patents to business R&D (less than one) indicates that the productivity of R&D performed by the business sector decreases as business R&D increases. The effect of R&D performed by higher education sector on patent activities is found to be insignificant in all specifications except of the first specification of the countries share in triadic patents families setting. A plausible explanation of these results is that the gestation period of higher education R&D is greater than that of business R&D since a part of higher education R&D is in the form of basic research which usually takes longer period to affect patent activities compared to applied research and development which is carried out by the business sector. In addition, funded research in the higher education sector might not be patented and could just get copyrights.

The effect of R&D performed by government is also found to be insignificant in all specifications. This insignificant effect has two explanations: first, R&D performed by government sector could be more in the defense sector rather than the civilian sector, which takes quite a while for that kind of R&D to produce an output (patent applications). Second, as indicated by Goolsbee (1998), since many developed countries have quite inelastic supply of scientists and engineers, a significant fraction of the increased government spending on R&D-either by direct provision of R&D activities or though subsidies-goes directly into higher wages to scientists and engineers. This means that an increase in government R&D activities will not result in increasing innovation but, rather, will reward human capital of scientists and engineers.

The spillover effect of OECD R&D pool is found to be positive and significant in two settings: patents registered in USPTO and countries share in triadic patents families, with a point estimate of 0.1 and 0.69, respectively. In addition, Patents show a significant, but weak, response to the second variable that captures the spillover effect, technology balance of payments ratio, in two settings: patents registered in EPO and countries share in triadic patents families with a positive point estimate of 0.007 and 0.004, respectively. This positive sign indicates that as the country becomes net exporter of technology (the technology balance of payments ratio is more than one), patent activities in that country is expanded. This means that technology exports induce patents activities which could be explained by the expected increase in innovative R&D activities within the OECD countries. However, it is clear that the patent elasticity to R&D pool and TBP ratio is low which means that OECD countries in the sample depend mainly on domestic R&D activities in boosting their patents.

Finally, with respect to the traditional technology transfer variables, patents are found to respond negatively and significantly to imports in the first two settings with a point estimate of -0.004 and -0.003, while the impact of FDI on patents is found insignificant. As indicated by Lake (1979) and Scherer and Huh (1992), the explanation of the negative effect of imports on patents is based on the idea that the increase in imports results may result in a lower profitability of domestic firms which leads to a reduction in R&D expenditures and thus, patent activities.

4.1. Patent elasticity in a distributed R&D lag model

As mentioned previously, many studies in the patent literature aim at estimating the impact of R&D on patents, particularly at a firm level, in order to figure out the optimal number of R&D lags that has a significant impact on patent activities. Most of these studies found that the contemporaneous and first R&D lag impact is the strongest among all other higher lags. Some other studies found that the impact of R&D lags on patents takes the pattern of a “U-shape” where the first and the last lags are the only significant lags (usually the last lag is the fourth or fifth year). The explanation of this U-shape pattern is discussed in details by Pakes and

Griliches, (1980) and (1984); Hall, Hausman, and Griliched (1984) and (1986), which refers to the lag "truncation effect" in the distributed R&D lag model. This means that the estimated coefficient on the last lag of R&D is positive and significantly higher than the coefficients of more recent, or intermediate years, R&D activities, which could be attributed to a possible lag-truncation bias because of the neglect of pre-sample R&D investment. In other words, since a part of the explanatory variables' series is not observed (the pre-sample part) and that the model considers the impact of only the observed (in-sample) explanatory variables, the precise lag coefficients will not be identified due to the correlation between the pre-sample part and the in-sample explanatory variables. This correlation is assumed to be between the pre-sample explanatory variables and only the last observed lag of the explanatory variables (correlation between the pre-sample and all other in-sample lags is zero).

The following table show the estimation of equation (4) in a distributed R&D lag model where I consider the first R&D lag impact on patent applications registered in EPO and USPTO, and on countries share in patents triadic families[4]. Table 4 empirical results of the lagged R&D model confirm those indicated in the current R&D model in the lagged dependent variable side as it shows that the number of patents in the previous period has the greatest positive impact on patents in the current period. It also confirms the positive and significant impact of GDP growth on the number of patents in the EPO and USPTO settings.

[4] I estimated equation (4) with up to 3 R&D lags and I faced the truncation effect problem in the USPTO model specification only, while all higher lags (2 and 3 lags) turned to be insignificant in the EPO and countries share in triadic patents families settings.

Table 4. System GMM estimation of patent elasticity to lagged R&D

	Dependent variable (Patents registered in EPO)		**Dependent variable (Patents registered in USPTO)**		**Dependent variable (Countries share in triadic patents families)**	
Parameter	(1) Values (Robust SE)	(2) Values (Robust SE)	(1) Values (Robust SE)	(2) Values (Robust SE)	(1) Values (Robust SE)	(2) Values (Robust SE)
Lagged dependent variable	0.94 (0.018)***	0.91 (0.023)***	.99 (0.0097)***	0.96 (0.021)***	1 (0.01)***	0.97 (0.023)***
LBERD	0.59 (0.25)**	0.29 (0.17)*	0.5 (0.18)***	0.36 (0.18)**	0.04 (1.47)	0.41 (1.01)
LGOVERD	0.085 (0.16)	0.009 (0.13)	-0.055 (0.4)	0.08 (0.056)	0.55 (0.6)	1.47 (1.06)
LHERD	0.51 (0.16)***	0.58 (0.13)***	0.53 (0.26)**	0.36 (0.13)***	1.8 (1.01)*	0.71 (0.92)
GGDP	0.019 (0.01)*	0.024 (0.009)***	0.014 (0.0095)***	0.01 (0.0087)***	0.04 (0.1)	0.049 (0.1)
TBP	0.00036 (0.0002)*		(0.0001) (0.00026)		0.0037 (0.0007)***	
RDPOOL	0.099 (0.044)**		0.086 (0.037)**		0.75 (0.33)**	
Imports		-0.0039 (0.0013)***		-0.0019 (0.0017)		-0.025 (0.017)*
FDI		0.002 (0.002)		0.0065 (0.004)*		0.003 (0.008)
Constant	-0.54 (0.97)	-0.52 (0.7)	-0.86 (0.67)	2.4 (1.04)**	-0.076 (6.4)	(3.34) (6.28)

Coefficients are significant at ***1%, **5%, and *10%.

The estimation of the lagged R&D model indicates a positive and significant effect of lagged R&D performed by business sector in the EPO and USPTO settings. Patents responsiveness to lagged business R&D is relatively more elastic in the USPTO setting compared to the responsiveness to the contemporaneous business R&D (the point estimates are 0.36 and 0.5 in the first and second specification of the USPTO setting, respectively), while there was no substantial difference between patents elasticity to lagged and current business R&D in the EPO setting. Lagged R&D performed by the higher education sector is found to be positive and significant in all specifications except the second specification in the countries share in triadic patents families setting.

The estimation of patent elasticity to lagged R&D shows a higher response of patents to lagged higher education R&D compared to lagged business R&D in most of the specifications. Lagged R&D performed by the government is estimated to be insignificant in all specifications and the same explanation of Goolsbee (1998) presented earlier is applied here (the increased government spending on R&D is translated mainly into higher wages to scientists and engineers and not higher patent activities).

The sign and estimated value of the impact of OECD R&D pool in the lagged R&D model (table 4) are found to be close to those in the current R&D model (table 3) while the TBP ratio shows a weaker impact on patents in the lagged R&D model (it is worth to say that the lagged TBP ratio and OECD R&D pool variables are found insignificant in all specifications, so I consider their contemporaneous effect only). Also, the lagged R&D model shows a negative impact of imports on patents, similar to the current R&D model, while the impact of FDI on patents turned to be positive and significant in the USPTO setting in the lagged R&D model, while it was insignificant in all specifications in the current R&D model.

5. Concluding Observation

The main findings of this study can be summarized as follows: first, only business R&D is found to have a positive and significant contemporaneous impact on patent activities among all other R&D-performing sectors. Second, the elasticity of patent activities with respect to higher education, as R&D-performing sector, shows a significant response of patenting only to lagged higher education R&D, while the response of patents to both contemporaneous and lagged government R&D is found to be insignificant. In general, the elasticity of patent activities to R&D expenditure is found to be low (inelastic) which means that none of the R&D-performing sectors is efficient enough in increasing the number of patents as the increase in R&D expenditure is not translated into a similar increase in patent activities. Finally, the technology spillover effect, which is measured by the technology balance of payment ratio and total OECD R&D, shows that countries with higher technology exports rate realize an increase in their patent activities. In addition, the total OECD expenditure on R&D is found to have a positive and significant impact on domestic patent activities.

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