Technological Forecasting & Social Change xxx (2016) xxx–xxx

Contents lists available at ScienceDirect

Technological Forecasting & Social Change

Patenting abroad: Evidence from OECD countries☆

Fragiskos Archontakis [a,*], Nikos C. Varsakelis [b]

[a] School of Economics, Business Administration & Legal Studies, International Hellenic University, 14 Km Thessaloniki, N. Moudania, 57001 Thermi, Greece
[b] Department of Economics, Aristotle University of Thessaloniki, and Laboratory of Economic Analysis and Policy, P.O. Box 184, 54124 Thessaloniki, Greece

ARTICLE INFO

Article history:
Received 25 December 2015
Received in revised form 20 June 2016
Accepted 27 July 2016
Available online xxxx

JEL classification:
O340
O330

Keywords:
International patenting
Exports
Extended gravity equation
OECD countries

ABSTRACT

The hypothesis that when the imitation risk is supported from exports then the decision to patent abroad is intensified is coming under scrutiny in the present paper, using data from 28 OECD countries. We investigate this issue, via two routes: the full sample for all source countries and a group-based. Higher exports increase the impact of imitation risk in the destination country on patenting abroad. The impact is positively correlated with the source country's size. Business cycle impact is statistically significant and positive but the counter intuitive sign of the IPR regime in the destination country demands further investigation. Finally, the distance variable is statistically significant and negative, verifying gravity model.

1. Introduction

The world experienced an unprecedented internationalization of economic activity during the last three decades. International trade and foreign direct investment dominated this internationalization assisting, among others, the developing countries to accelerate their growth rates (e.g. Schneider, 2005). Internationalization, on the other hand, led to the re-allocation of global economic activity, with OECD countries becoming gradually knowledge and technology oriented economies. In this environment, inventors from a country faced the dilemma of expanding the protection of their invention in foreign countries.

As a result of the trend in international patenting during the last two decades, as Paci et al. (1997) note, firms in developed countries aim at the commercial exploitation of their invention in foreign countries either through exports or through licensing. Royalties and licence fees become more and more an important source of international income (Beattie, 2012) and, accordingly, the decisions of these inventors are affected by the intellectual property rights protection framework of the destination country.

Research has moved towards identifying the factors on which this decision might depend on, given the difficulty to identify the determinants of patent value (e.g. (Ernst et al., 2010; Petrick and Echols, 2004). A track of the literature has followed Eaton and Kortum (1996) who argue that imitation risk plays a significant role in the decision to patent in a foreign country. Another track of the literature has followed Smith (1999, 2001) who related the decision to export to a destination country with the intellectual property rights protection framework in this country.

This paper aims to explain the decision to patent abroad based on the assumption that imitation risks do matter in relation with the country's exports to the destination country since a certain share of the patents granted by the source country patent office has international economic value and the patentee seeks protection in foreign markets. It relies on an augmented gravity model to explain international patenting of 28 OECD countries using data for the period 1995–2005 when most of the major institutional changes regarding intellectual property rights after the TRIPs agreement has been implemented. In order to make our results more robust, we decided to follow in our empirical estimations two routes: the full sample for all home countries and a group-based ("big" and "small and medium" home countries), dividing countries according to their level of innovative activities. We quantify the above mentioned hypothesis, using panel data methodology, in the following way: higher exports from source to destination country imply higher impact of imitation risk in the destination country on patenting abroad. In particular, where the imitation risk has a positive impact on the decision to patent in a foreign country, the impact

☆ We would like to express our gratitude to two anonymous referees, the Editor/Associate Editor of this journal, Jorge González Chapela and Theon van Dijk for their helpful comments. Author names appear in alphabetical order - no senior authorship assigned. The usual disclaimer applies.

* Corresponding author.
E-mail addresses: f.archontakis@ihu.edu.gr (F. Archontakis), barsak@econ.auth.gr (N.C. Varsakelis).

http://dx.doi.org/10.1016/j.techfore.2016.07.044
0040-1625/© 2016 Elsevier Inc. All rights reserved.

will be even more positive the higher the level of exports from the source to the destination country. The result holds for the full sample of countries and for the group of "small and medium" ones. However, for the group of "big" countries the positive impact is not affected by the interaction. Even though the individual variables, imitation risk and exports, seem to impact the decision to patent abroad, the complementarity (interaction) is not statistically significant suggesting that patenting abroad decision for the group of "big" countries is pursued for other reasons than protecting exports.

The rest of the paper is organized as follows. Section 2 presents the theoretical background and the hypotheses setting. Section 3 presents the model and the data. Section 4 presents the empirical results and a discussion. Finally, Section 5 offers some concluding remarks.

2. Theoretical background and hypotheses setting

Because national patents protect inventions only in domestic markets, inventors may decide to patent abroad. It is a fact that patenting abroad has increased dramatically during the last three decades as data from the WIPO database reveal. From the same database, however, we conclude that a fraction of national patents is also patented abroad. Some of the inventions do not have any economic value (Cohen and Levin, 1989) and consequently the patentees would never try to patent abroad given that patenting abroad bear significant administrative and financial costs[1]. Then again, some of the patentees who could put into effect the commercial exploitation of their patents do not identify a technological or entrepreneurial opportunity and subsequently leave their patents idle at the national patent office (Goniadis and Varsakelis, 2012). From the patentees that, eventually, exploited commercially their patents in the national market, some do not aim at an international route and some others do not patent abroad because they cannot see technological or entrepreneurial opportunities in other markets. The patentees, who recognise a technological or entrepreneurial opportunity in international markets and aim at the international exploitation of their patent, examine next whether this opportunity is country specific (usually the home country) or generic. If the invention is home specific, the patentees do not have an economic incentive to patent abroad. If the invention is generic, a potential economic value exists, even with some minor modifications of the invention, and the patentees consider the case of patenting abroad. To the extent that patentees perceive the potential economic value of their patents in foreign markets they should examine the countries where patenting their inventions is profitable. They compare the potential economic benefit from the patent with the cost of patenting in the specific country. This cost-benefit analysis influences the selection decision of the countries that are worth to patenting at. Hence, the decision to patent abroad takes a strategic character rather than of a simple short run decision.

Internationalization strategy may follow three tracks: exports, licensing and foreign direct investment (FDI). Foreign direct investment used to follow the stand alone strategy in the previous decades, that is a production unit produced the entire product to serve the destination market. However, this strategy has changed during the last decades and multinational firms try to optimize their production process by increasingly locating the various stages across different countries; they are organized within global value chains (GVCs)[2], as illustrated by the high correlation between FDI stocks in countries and their GVCs participation index (OECD, 2014). In the case of GVC, the mother company transfers knowledge to its subsidiary in the foreign country related to the specific stage of production (e.g. a certain piece of machinery). Based on this fact, the local rival firms could replicate only this partial knowledge. Therefore, patenting in the destination country might not be economically beneficial since GVCs spread in a large number of countries and the patent document "total knowledge" is difficult to match with specific stages of production. We argue that the firms organised as GVC are more interested in patenting in the final product markets (domestic or foreign). To our knowledge, literature so far has analysed the flow of intangibles in a supply chain context by case studies only (Hall and Andriani, 1998; Choi et al., 2004) where there was privileged access to firm data. According to recently published data from OECD (October 2015; OECD-WTO TiVA initiative[3], but they are presented in five-year intervals for the period 1995–2008 and annual thereafter) the Foreign Value Added Share of Gross Exports averages range from 11.2% in Japan to 54.2% in Luxembourg for the period of 1995–2011. Overall for the large, in terms of patenting abroad, OECD countries this share is lower than 25%.

In summary, for the reasons presented above, although the GVCs are admittedly important in the context of global manufacturing and value chain (e.g. Hall et al., 2011) we opt to focus on gross international trade data.

In the case of international trade and foreign direct investment the patentees extract the monopolistic rent of the patent while in the case of licensing extract a part of the economic value of the inventions through royalties and fees. In all cases, the inducement to patent in the destination country is the risk of imitation from local firms and firms from other countries which have commercial interest in the destination country, extracting that way part or sometimes the full economic value of the invention. The imitation risk is lower the higher the tacit component while in advanced industrial countries, intellectual property rights may impede imitation of certain capabilities (Teece, 2004).

Empirical literature, using data mainly from the US and other big innovative countries, has tried to determine the factors which are considered in the answer to the question: "Where do I patent?" More specifically, it has mainly focused on the imitation risks that inventors face in other countries, even though the inventor protects the invention at home through a domestic patent. In their seminal paper, Eaton and Kortum (1996) considered international patenting in a model to explain the impact of world innovation on economic growth. They found that the physical distance, the human capital, as a proxy for the imitation risks, and the patent protection framework of the destination country affect the patenting abroad decision (the distance's importance is also confirmed in (Drivas and Economidou, 2014)). Eaton and Kortum (1996, 1999) argue that imitation cost plays a significant role in the inventors' decision to patent their idea in a foreign country. This cost increases with the knowledge base of the outsiders and the commercial interest to the destination country. Based on the Eaton and Kortum data set, McCalman (2001) verified these results, in an effort to estimate the impact of the General Agreement on Tariffs and Trade (GATT) – Uruguay round on the transfer of income and McCalman (2005) estimated the impact of the Trade-Related Aspects of Intellectual Property Rights (TRIPS) agreement on the short and long run growth. Those findings were further verified by Yang and Kuo (2008) with data for the OECD countries and Archontakis and Varsakelis (2011) who adopted a gravity model to explain the US residents international patenting in the OECD countries.

Besides the imitation risks, another track examined specific aspects. For example, Harhoff et al. (2007) assessed to what extent validation and renewal fees as well as translation costs affect the validation behaviour of patent applicants. They rely on a gravity model that aims at explaining patent flows between inventor and target countries within the European patent system. To further enforce this evidence, Ulku (2007) found that an increase in the share of researchers in labour has a positive effect on innovation *only* in the big market OECD countries that include the G7. Acemoglu and Linn (2004) using data at firm

[1] As reported in Financial Times: "According to EU estimates, it costs about €30,000 to get a bundle of national patents to cover all 27 member states…" Financial Times, Jun 22, 2012 – accessed on 27 Sep. 2012: www.ft.com/cms/s/0/cbf2298c-bbab-11e1-90e4-00144feabdc0.html.

[2] We would like to thank one of the anonymous referees for pointing out this issue.

[3] Source of data from the OECD's link: http://www.oecd.org/sti/ind/measuringtradeinvalue-addedanoecd-wtojointinitiative.htm.

Please cite this article as: Archontakis, F., Varsakelis, N.C., Patenting abroad: Evidence from OECD countries, Technol. Forecast. Soc. Change (2016), http://dx.doi.org/10.1016/j.techfore.2016.07.044

level found support for the theory that proclaims that market size is significantly important for effective R&D sector (although they admit that the pharmaceutical sector might be non-representative due to the fact that it is more research oriented). Finally, as Hall (2004) found that for new entrants, especially in complex product industries, ownership of patents may have become an important signal of viability, as the venture capitalists argue when considering funding these firms earlier in the life cycle process, patents are essential to provide a claim on the most important asset of the firm, its knowledge capital.

A significant share of the empirical literature relates trade with the imitation risks and consequently with patenting abroad. Maskus and Penurbarti (1995) show that it is not crystal-clear how patent regimes (i.e. weak *versus* strong IPRs) affect trade. On the other hand, Smith (1999, 2001) related the threat of imitation and export sensitivity to patent rights. Among other results, she found that weak patent rights protection is a barrier to US exports (only to countries that pose a strong imitation threat). Rafiquzzaman (2002) and Co (2004) used export data in order to focus on IPR protection issues. Rafiquzzaman (2002) found that Canada exports more to countries with stronger patent rights regime, while Co (2004) using data for the US found that patent rights regime *per se* do not affect US exports. Finally, Ivus (2010) investigated the impact of stronger IPR in developing countries on the exports of innovating developed world into their markets: she found that strengthening IPRs in developing countries raises the value of developed countries' exports (in patent sensitive industries).

Literature, although not extensively, has provided some evidence that trade is also a significant factor in the decision to patent abroad because firms that export in foreign markets have an incentive to protect their innovation from imitation in the destination country. Dosi et al. (1990) provided arguments and some evidence that bilateral trade between two countries is correlated with the international patenting between the two countries. Putnam (1996) found that international patenting of a country is correlated with the market size of the destination country; implicitly assuming that trade does really matter. Finally, Yang and Kuo (2008) provided further evidence on the correlation between exports and international patenting.

Since the output of the innovation activity is accruing to the society due to its public good character, the innovator's actual reward is lower than the expected one (Arrow, 1962). The greater danger, however, for the innovator is the imitation of the newly invented goods (or processes) either by domestic or foreign competitors. In such a case, competitors will be able to offer new products in the market, usually at cheaper prices (Ginarte and Park, 1997) and thus, the innovator would not be able to fully exploit the monopolistic advantage from its R&D activity.

Therefore, the decision to patent in a foreign country depends simultaneously on the decision to export in this country and on the imitation risks. For example, if a firm aims to export its products in a country with insignificant innovative activity, and consequently negligible imitation risks, may decide to export without taking the cost of patenting in this country. In such a case the firm aims to exploit the first entrance strategic advantage against its potential future competitors.

Based on the above arguments, we explore whether the decision to patent abroad gains by simultaneous changes in the imitation risk and exports.

3. Methodology

3.1. The model

In order to empirically test the hypotheses formulated in the previous section we use an augmented gravity model. This model allows a comparison of international patenting between OECD countries, since this choice comprises the bulk of patenting activity (e.g. in the world share of countries in triadic patent families the OECD-Total is over 90%, OECD (2016); also according to our WIPO dataset regarding intra-OECD countries' foreign patenting activity accounted to almost 65% for the period under examination. The model is checking at the same time for possible similarities/differences given the size of the source country. The original gravity equation was first introduced by Tinbergen (1962). Leamer & Levinsohn (1995, p.1384) claim that such gravity models provide "… some of the clearest and most robust empirical findings in economics". Gravity models have been used extensively in the international trade literature (for instance Smith (1999, 2001) and Rose (2004) and international patenting (for example Picci, 2010; Archontakis and Varsakelis, 2011; Ghemawat and De La Mata, 2015).

Eq. (1) explains patenting of country's j residents (home country hereafter) in destination country i (destination country hereafter) at time t:

$$P_{j,i,t} = GP^{a}_{j,t}H^{b}_{i,t}D^{c}_{j,i} \tag{1}$$

where $P_{j,i,t}$ are the patent flows from the OECD country j to country i at time t. The gravity variables are: the total number of patents the residents of the home country j registered ($P_{j,t}$); patenting in the destination country ($H_{i,t}$); the physical distance $D_{j,i}$ between the home country j and the destination country i. G is a generic term which includes the rest relevant variables of the augmented ("augmented" in the sense of using more variables, as opposed to the original Anderson (1979) contribution) gravity equation. In this paper, G includes the trade variable (EX) and an interaction term (INT), which will be defined later[4]. It also includes variables used in literature such the intellectual property rights protection (IPR) and the business cycle (BC) in the destination country. Finally, the generalization of the gravity model by introducing powers is common in the literature.

Taking the logarithms of Eq. (1) we derive the following specification that will be estimated:

$$y_{jit} = c + a'X_t + \varepsilon_{jit} \tag{2}$$

where y_{jit} is the dependent variable, X_t is the vector of the explanatory variables, ε_{jit} represents the disturbance term, and a is the vector of parameters to be estimated. More specifically, $y_{jit} = \log P_{j,i,t}$ is the log of number of patents from residents of the home country j in destination country i (denoted as $LPAT$).

The vector of explanatory variables X_t includes: $\log P_{j,t}$ is the logarithm of total number of patents the residents of the home country j registered in their country (denoted as $LOUT$) and is used to capture the first gravity variable i.e. the innovation activity in the home country; the variable $\log H_{i,t}$ is the logarithm of the number of patents registered in destination country i by nationals of the destination country and foreigners[5] (denoted as $LHOST$) and is used as the second gravity variable; actually, this variable captures the imitation risks in the destination country. This variable could be considered as an alternative to the human capital which was used by Eaton and Kortum (1996) and Yang and Kuo (2008) as proxy for the imitation risks. However, Griliches (1979), Pakes and Griliches (1980) and Griliches (1990) defined the output of the innovative activity of a country, Y_i, as a function of the inputs (Z_{it}) supplied to the country i and the stock of knowledge (K) available in the public domain:

$$Y_{it} = f(Z_i; K) \quad ; \quad Z_i = [R_i, H_i]$$

[4] The decision to patent abroad is a two stage decision process when the unit of analysis is the firm. At the first stage the firm decides to export or not. If the firm decides to export, then the second stage refers to the country of destination of exports and patenting. Unfortunately, this information is not available at the national level. Future research could provide interesting results concerning this issue using data at firm level.

[5] A patentee, who wishes to protect the invention abroad, should patent in countries with high innovation activity and strong knowledge base. The number of patents in the destination country provides strong representation of innovation since the number of patent applications is proportional to the extent of innovation (Watanabe et al., 2001).

Please cite this article as: Archontakis, F., Varsakelis, N.C., Patenting abroad: Evidence from OECD countries, Technol. Forecast. Soc. Change (2016), http://dx.doi.org/10.1016/j.techfore.2016.07.044

where $f(.)$ is the knowledge production function (KPF). The vector of inputs Z_i includes the stream of R&D expenditures (R_i) during the past τ years ($\tau \geq 0$); and the stock of human resources (H_i) (e.g. scientists). The stock of knowledge K available to all innovative countries is the cumulative output of the knowledge production function. Hence, our variable *LHOST*, gives more information for the imitation risk than the human capital alone. Patents, as the output of the knowledge production function of a country (Pakes and Griliches, 1980; Griliches, 1990) incorporate information not only on human capital but also on R&D expenditures, knowledge spillovers, the absorptive capacity and the efficiency of the national innovation system. The decision to patent in a foreign country depends on the imitation risk. Imitation comes from two sources (Eaton and Kortum, 1996). One source is the imitation by local companies in the destination country; and another is the possible imitation by companies established in other than the destination country which target commercially the destination country. If a patent does not protect an invention in the destination country outsiders will imitate and sell their product to the destination country. If many outsiders register their patents in a country, they consider their technological and commercial potential. As long as an invention is not protected adequately in such countries, outsiders have an incentive to imitate. This risk increases with the knowledge base of the outsiders and their commercial interest to the destination country. A proxy for this latent variables is their patents granted in the destination country (Archontakis and Varsakelis, 2011). Thus, *LHOST* refers to the destination market and in this market not only nationals can imitate but also the residents of other countries could sell their imitation products in the destination market. $\log D_{ji}$ is the log of the physical distance between the home country j and the destination country i (denoted as *LDIST*); the variable BC_{it} is a proxy for the business cycle effect on the decision of the source country patentee to register a patent in destination country i (denoted as *BUSCYC*); IPR_i is an index introduced by Ginarte and Park (1997) which captures the intellectual property rights protection framework in the destination country; $\log EX_{jit}$ is the logarithm of exports of the home country j to destination country i in time t (denoted as *LEXP*) and its use follows the relevant literature (e.g. Smith, 1999). Finally, INT_{jit} is an interaction term (see also Section 3.2 for the definition).

The data we have in hand consists of 28 OECD countries across 11 years, 1995–2005. Iceland was included only as a recipient country since no patent with origin from Iceland has been registered during the examination period. Thus, for each individual source country there are a maximum of $27 \times 11 = 297$ observations. In order to make our results more robust, we decided to empirically investigate Eq. (2), via two routes: the full sample for all source countries and a group-based ("big" and "small and medium" source countries). The groups were formed in the following way: we selected the sum of patents registered in the source country to its residents (variable *OUT* in our data set) during the full sample period as the most representative index of the volume of the innovative activity of a country. Switzerland was the "cut-off-point" country (that corresponds to the median) of the variable *OUT*. Thus, we opted to dividing the data in two groups, i.e. of "big", and "small and medium" countries:

i. the "full set" (full sample) with all source countries.
ii. a group-based, in terms of national innovative activity:
   a. The group of "big" countries consisting of the most innovative countries: Australia, France, Germany, Japan, Korea, United Kingdom and United States.
   b. The group of "small and medium" countries consisting of the rest innovative countries.

Panel data should be used because of several benefits, i.e. help to extract more information, avoid multicollinearity problems and give more efficient results; better identify and measure effects that are not detectable in pure cross-section or pure time-series data. See Baltagi (2001), Cameron and Trivedi (1998) and Greene (2003) for more examples and technical details. Furthermore see Mátyás (1997) and Egger (2000) for the technical details on the empirical estimations of gravity models. The individual effect in our case since it is a three way panel are the pair of the home and destination country. For example, the pair of UK and Portugal comprises one unit and UK and Poland a different unit.

3.2. Data

Amongst a wide variety of new measures of national technological capabilities (see for a review (Archibugi and Coco, 2005) patent counts and, more generally, patent-based indicators at country level are more frequently used to assess countries' innovation performance (Griliches, 1990; OECD, 2001; Guellec and van Pottelsberghe de la Potterie, 2001; Khan and Dernis, 2006; Léger, 2007; Van Pottelsberghe de la Potterie and de Rassenfosse, 2008). It is worth noting, that patents granted in different patent offices may have different relative weight. For example, the Japanese patent office requires that separate applications be made for each technical aspect of an invention (Paci et al., 1997). Consequently, Van Pottelsberghe de la Potterie and de Rassenfosse (2008) suggest: «Japanese priority filings to be divided by three, as Japanese patents are on average composed of fewer claims (about 8 in 2003, as opposed to 24 in the patents filed at the USPTO)». Hence, we divided the reported number of Japanese patents by three.

More specifically, for the empirical estimation of Eq. (2), we use the following variables and the corresponding data. Data on patents were from the World International Patents Organization database (WIPO).

LPAT, the natural logarithm of the patent flows from the source country j to the target country i; we used the patents granted to residents in the OECD countries for the period 1995–2005.

LOUT, the natural logarithm of the total number of patents registered in home country j to its residents.

LHOST, natural logarithm of the patents registered in destination country i by nationals and foreigners of the rest of the sample countries in the OECD countries.

LDIST, the natural logarithm of the weighted distance between the economic centers of the partner countries as proposed by the *Centre D'Etudes Prospectives et D'Informations Internationales* (CEPII).

LEXP, the natural logarithm of the exports of country j to destination country i. Data are from the OECD database.

$INT =$ the interaction term between exports (*LEXP*) and imitation risk (*LHOST*) is defined as the product of the variable *LEXP* and *LHOST*;

$INT = LEXP * LHOST$.

BUSCYC: a variable to capture the business cycle impact in the destination country i, i.e. the difference between trend (calculated using the Hodrick–Prescott filter) and current growth rate. When *BUSCYC* is negative, the destination economy slows down; when it is positive the economy grows. Data are from OECD database.

IPR: an index which captures the intellectual property rights protection framework of the destination country i: For the measurement of the patent rights protection, we use the Ginarte and Park (1997) patent rights protection index. They constructed the patents rights index using a coding scheme applied to national patent laws. They examined the following categories of patent laws: (1) extent of coverage, (2) membership in international patent agreements, (3) provisions for loss of protection, (4) enforcement mechanisms, and (5) duration of protection. Each of these categories (per country) was assigned a value ranging from 0 to 1. The unweighted sum of these five values constitutes the overall value of patent rights index. This index is time invariant in our sample period.

Table 1 presents the descriptive statistics of the explanatory variables for the full sample and for the individual groups. Table 2 provides the correlation matrix for the full sample. The correlation matrices for the two groups are similar to Table 2. Consequently, the level of correlations indicates that problems of multicollinearity are not likely to be manifest in the regression models.

Please cite this article as: Archontakis, F., Varsakelis, N.C., Patenting abroad: Evidence from OECD countries, Technol. Forecast. Soc. Change (2016), http://dx.doi.org/10.1016/j.techfore.2016.07.044

Table 1
Descriptive statistics of explanatory variables.

	Explanatory variables	Mean	Std. Dev.	Min.	Max.
Full sample	HOST	28575.6	76910.7	0	393088
	OUT	18244.7	39486.8	71	202776
	EXP	5016332	1.52e+07	174.2	3.02e+08
	BUSCYC	0.164	1.852	−12.176	5.2
	DIST	5536.2	5374.4	141.4	19537.1
	IPR	4.165	0.515	2.65	4.88
Big countries	HOST	26021.5	73985.8	0	393088
	OUT	63309.9	54789.4	7744	202776
	EXP	1.05e+07	2.04e+07	2956.5	2.11e+08
	BUSCYC	0.169	1.853	−12.176	5.2
	DIST	7255.2	5220.9	281.8	18891
	IPR	4.157	0.518	2.65	4.88
Small and medium countries	HOST	29469.5	77894.8	0	393088
	OUT	1618.6	1237.5	71	7877
	EXP	3097780	1.24e+07	174.2	3.02e+08
	BUSCYC	0.162	1.852	−12.176	5.2
	DIST	4934.5	5297.3	141.45	19537.1
	IPR	4.169	0.515	2.65	4.88

Note: The values of the explanatory variables are stated in nominal values, i.e. before taking logarithms (which are used for the empirical analysis).

4. Empirical results and discussion

Table 3 presents a summary of the estimation results: the full set of our sample countries, the group of "big" countries and the group of "small and medium" ones. The econometric estimation followed was the panel random effects (RE) for the full sample, the "small and medium" countries and the "big" countries group.

We report two modes for each set (the full sample, the group of "small and medium" counties, and the group of "big"); the Mode 1 without the interaction term and the Mode 2 with the interaction term. We note that we have also lagged our right hand side variables *LHOST* and *LEXP* (and as a result their product, i.e. the *INTER* variable, as well) one period to control for the possible endogeneity of current values of the explanatory variables (see also Bloom and Van Reenen, 2002). As a result, this change does not noticeably affect the previous results reported in the main body of the paper.

The elasticities, for variables defined in logarithms, are equal to the partial derivatives of *LPAT* with respect to the corresponding variable. For example, the elasticity of the patenting abroad with respect to the size of patenting in the source country, *LOUT*, for the full sample (Mode1) is equal to 0.593. Hence, an increase in the size of patenting at the home country by 1% causes an increase of its patenting abroad by 0.6%. This finding suggests that as the patents produced by the citizens of a country increase the number of patentees who will seek the commercial exploitation of their invention in foreign counties, increases too. Even more, during the examined period our finding indicates that the majority of patentees aim not only at the domestic market but simultaneously at foreign markets for the reasons explained above. The more globalized the knowledge creation becomes, the less protection a patentee receives in a single country; therefore, in order to protect the competitive advantage of its invention she should exploit the possibility of patenting abroad too.

The estimated coefficient of the *LHOST,* which is used in this paper as a proxy for the imitation risks, is statistically significant in all econometric models without the interaction term. The estimated elasticity of patenting abroad with respect to the *LHOST* for the three groups follow a concrete ordered pattern, that is: "big" countries exhibit the higher and the "small and medium" countries the lower elasticity; the estimated elasticity for the group of "big" countries is 0.788, for the full sample is 0.599 and for the group of "small and medium" countries is 0.495. The positive sign indicates that the decision to patent in a foreign country increases with the volume of patenting in the destination country that is with the expected imitation risks. This result verifies previous findings (Eaton and Kortum, 1996; Yang and Kuo, 2008) who found that the decision to patent abroad depends on a degree on the risk of imitation. The ability to imitate, and consequently the imitation risk, is correlated to the size of the innovative activity in the destination country. We have reached the same conclusion, by using a different methodological approach.

The physical distance variable *LDIST* is significant and negative as the gravity model proposes, for all estimated modes. This finding verifies the results found by Eaton and Kortum (1996), Yang and Kuo (2008) and Archontakis and Varsakelis (2011)) for the US.

Business cycle (*BUSCYC*) has similar behavior in all modes, with respect to statistical significance and sign. The sign of *BUSCYC* is positive. As Geroski and Walters (1995) point out, major innovations and patents are pro-cyclical and the causal relations run from variations in demand to variations in patenting. In this paper, we are interested in explaining the cross-country *versus* cross-time variation of patenting from a source country to the rest countries of the OECD. Our result verifies the findings of Geroski and Walters (1995) since patenting from the source to the destination country is positively correlated to the BUCYC variable, which is when BUSCYC increase, the economy of the destination country grows, patenting from the source to the destination country increases. Hence, patenting abroad seems to be pro-cyclical, indicating that it is rather "demand pulled".

The inclusion of the interaction term changes to negative the signs of the variables, *LHOST* and *LEXP*. We accentuate that the estimated coefficients of these variables do not have economic meaning since the corresponding partial derivatives (elasticities) are estimated by taking into account the interaction term.

The partial derivative (elasticity) of the dependent variable *LPAT* with respect to *LHOST* variable depends on the values of the *LEXP* and *vice versa*. The partial derivative of the depended variable *LPAT* with respect to *LHOST* is:

$$\frac{\partial LEXP}{\partial LHOST} = \hat{a}_2 + \hat{a}_6 \cdot LEXP \tag{3}$$

Where $\hat{a}_2$and $\hat{a}_6$ are the estimated coefficients of the *LHOST* and the interaction term respectively. Since we are interested in the sign of this particular derivative over a range of the *LEXP* variable, we proceed to estimate the sign of (3).

According to Hirschberg and Lye (2005, 2010) for $w^* = \frac{\hat{a}_2}{\hat{a}_6}$, where w stands for *LEXP*, the upper and lower critical values of the Fieller's 100(1-a) % confidence interval are the roots of the quadratic equation $kw^2 + 2lw + c$ where:

$$k = \hat{a}_6 - t^2_{a/2} Var(\hat{a}_6)$$

$$l = -\left(t^2_{a/2} Cov(\hat{a}_2, \hat{a}_6) - \hat{a}_2 \cdot \hat{a}_6\right)$$

$$c = \hat{a}_2 - t^2_{a/2} Var(\hat{a}_2)$$

Table 2
Correlation matrix of explanatory variables (full sample).

	LHOST	LOUT	BUSCYC	LDIST	IPR
LHOST	1.000				
LOUT	−0.035	1.000			
BUSCYC	−0.020	−0.001	1.000		
LDIST	0.199	0.161	−0.031	1.000	
IPR	0.515	−0.011	−0.060	−0.047	1.000

Please cite this article as: Archontakis, F., Varsakelis, N.C., Patenting abroad: Evidence from OECD countries, Technol. Forecast. Soc. Change (2016), http://dx.doi.org/10.1016/j.techfore.2016.07.044

Table 3
Full set and group panel estimations (LPAT is the dependent variable).

	Full sample		Small and medium countries		Big countries	
	Mode 1 (RE)	Mode 2 (RE)	Mode 1 (RE)	Mode 2 (RE)	Mode1 (RE)	Mode 2 (RE)
LOUT	0.593***	0.598***	0.430***	0.431***	0.413***	0.403***
	(0.0295)	(0.292)	(0.058)	(0.0577)	(0.0813)	(0.082)
LHOST	0.599***	−0.0403	0.495***	0.142	0.788***	−0.175
	(0.0237)	(0.138)	(0.0295)	(0.169)	(0.0378)	(0.278)
BUSCYC	0.018***	0.018***	0.018**	0.018**	0.015*	0.015*
	(0.0056)	(0.0056)	(0.0072)	(0.0072)	(0.0087)	(0.0086)
IPR	−0.754***	−0.743***	−0.650***	−0.639***	−0.812***	−0.831***
	(0.0525)	(0.0524)	(0.0686)	(0.0687)	(0.0796)	(0.0796)
LEXP	0.115***	−0.287***	0.062**	−0.172	0.239***	−0.305*
	(0.0257)	(0.0900)	(0.0307)	(0.115)	(0.0489)	(0.164)
INT		0.046***		0.0262**		0.0645***
		(0.0098)		(0.012)		(0.0185)
Distance	−0.142***	−0.158***	−0.135**	−0.146**	−0.155*	−0.194**
	(0.048)	(0.0476)	(0.0573)	(0.057)	(0.087)	(0.088)
Constant	−4.851***	0.760	−2.646***	0.514	−5.803***	2.728
	(0.533)	(1.314)	(0.751)	(1.675)	(1.301)	(2.787)
Nr Obs	4857	4857	3176	3176	1681	1681

Notes.
a) Standard errors in parentheses.
b) ***significant at the 0.01 level; **significant at the 0.05 level; *significant at the 0.10 level,
c) *LPAT*, the natural logarithm of the patent flows from the source country *j* to the target country *i; LOUT*, the natural logarithm of the total number of patents registered in home country *j* to its residents; *LHOST*, natural logarithm of the patents registered in destination country *i* by nationals and foreigners of the rest of the sample countries in the OECD countries; *BUSCYC* is a variable to capture the business cycle impact in the destination country *i*; *IPR* is an index which captures the intellectual property rights protection framework of the destination country i; *LEXP*, the natural logarithm of the exports of country *j* to destination country *I*; INT_{jit} = the interaction term between exports and imitation risk (*LHOST* in our database) is defined as the product of the variable *LEXP* and *LHOST*; *Distance*, the natural logarithm of the weighted distance between the economic centers of the partner countries.

For the full sample estimations (Mode 2), the value of the partial derivative (elasticity) at the mean of the $LEXP = 13.696$ is equal to 0.589 similar to the estimated elasticity in the equation without the interaction term (0.599). We use direct tests to determine the critical values (c_U and c_L) of the *LEXP* above (below) which the Fieller's 95% confidence interval for the partial derivative is defined. Using the estimations from Mode 2, we found that the equation $kw^2 + 2lw + c$ has two roots, $c_U = 1.519$ and $c_L = -1.66$. Hence, for values of *LEXP* between −1.66 and 1.519 the partial derivative is zero or its sign is uncertain. However, since the *LEXP* variable takes values >5.16 the partial derivative is positive and monotonic taking values from $\frac{\partial LPAT}{\partial LHOST} = 0.197$ for the *min* $LEXP = 5.16$ to the *max* $LEXP = 19.525$ is $\frac{\partial LPAT}{\partial LHOST} = 0.858$.

The same discussion applies to the group of “big” countries where the elasticity of the patenting abroad with respect to *LHOST*, calculated at the mean of the *LEXP* variable, is equal to 0.78 similar to the estimated elasticity in the equation without the interaction term (0.788). For the group of “small and medium” countries the elasticity of the patenting abroad with respect to *LHOST*, calculated at the mean of the *LEXP* variable, is equal to 0.37 lower than the estimated elasticity in the equation without the interaction term 0.495.

The sign of the partial derivative for the group of “small and medium” countries is always positive since the two estimated coefficients, *LHOST* and *INTER* are positive. Finally, using the estimations for the group of “big” countries with the interaction term (Mode 2), we found that the equation $kw^2 + 2lw + c$ has $c_L = -2.884$ and $c_U = 2.611$. Since *LEXP* takes only positive values the partial derivative is greater or equal to zero when the equation includes the interaction term which is also statistically insignificant.

Hence, the partial elasticity changes over a range of values of the *LEXP*. The function that relates the partial elasticity with *LEXP*, i.e. Eq. (3), is linear and monotonically increasing with slope the coefficient of the interaction term. As can be seen in Fig. 1, the slope of the elasticity with respect to *LEXP* is steeper for the “big” countries than the corresponding for the “small and medium” countries. It seems that the elasticity of patenting abroad with respect to the imitation risk (*LHOST*) is more sensitive to changes in the *LEXP* for the “big” than for the group of “small and medium” countries. Consequently, since the variable *LHOST* has been used in this study as a proxy for the imitation risks in the destination country, the impact of the imitation risks on the decision to patent abroad is correlated to the volume of trade from the country of the patentee to the destination country. These empirical findings, the correlation between international trade and patenting abroad is similar to those found by Dosi et al. (1990), Smith (1999, 2001) and Yang and Kuo (2008) given the limitation that 25% of the total volume refers only to parts of products (GVCs) of international trade.

The sign of the *IPR*, contrary to common belief is negative for all groups. Eaton and Kortum (1996) found that countries providing strong protection are more attractive destinations for foreign patents, using a relative patent index created by Rapp and Rozek (1990) based on surveys of business and government officials and an examination of patent laws. However, Bosworth (1984) finds that his “Patent Law” differences variable is not significant in explaining the patent applications from/into the UK. In this paper, we used the patent index developed by Ginarte and Park (1997) based only on the examination of laws. The negative sign may be attributed to three reasons: First, since a stronger IPR protection framework implies a higher cost of patenting, inventors possibly decide to protect their inventions only in a small fraction of countries. Second, Ginarte and Park (1997) and Bosworth (1984) distinguish between statutory *versus* actual protection (or formal *versus* informal), which is whether “laws on the books” are carried out. Especially they note that “if there is any overestimation of patent rights and protection, it should be the OECD's measures”. Consequently, although our result is rather counter-intuitive, there might be the case for further investigation and construction of alternative IPR protection indices. Finally, the negative coefficient of the IPR might be due to the blocking effect of patents. Stronger IPRs may reduce the applications to foreign patent offices of narrower less innovative patents and only permit bigger step innovations.

5. Concluding remarks

Conventional wisdom suggests that inventors-patentees tend to protect themselves against imitation, in the countries where such a risk is high. Imitation risk is higher, the higher the innovative activity of the

Please cite this article as: Archontakis, F., Varsakelis, N.C., Patenting abroad: Evidence from OECD countries, Technol. Forecast. Soc. Change (2016), http://dx.doi.org/10.1016/j.techfore.2016.07.044

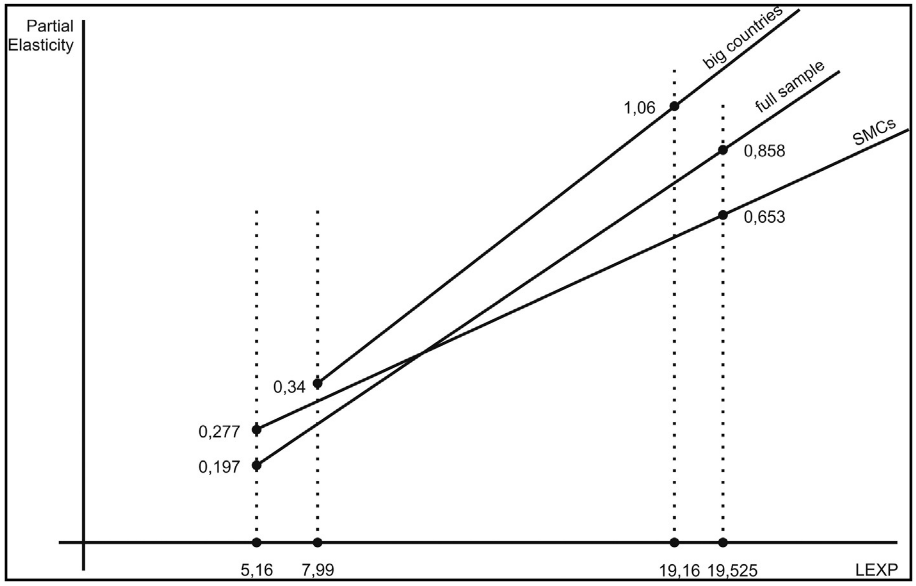

Fig. 1. The slope of the partial elasticity $\frac{\partial LPAT}{\partial LHOST}$ with respect to *LEXP*.

country. Furthermore, there is the perception that the cost of patenting in another country is lower, the smaller the geographical distance between the home and the destination country. Previous empirical research has used gravity models to investigate the internationalization of innovation and patenting.

The present paper has built upon this research and put these issues under further scrutiny. Using data from 28 OECD countries, for the period 1995–2005 (Iceland was included only as a destination country), to explain the variation of patent flows from the source country *j* to the target country *i* (the dependent variable) within the framework of an extended gravity model. In order to make our results more robust, we investigated this model, via two routes: the full sample for all source countries and a group-based ("big" and "small and medium" source countries).

Imitation risk in destination country is significant in explaining the patenting abroad decision and so is for the exports from the source to the destination country. Even though exports on their own contribute to patenting abroad, the real gains to patenting abroad come from complementing (interaction) imitation risk with exports. When the imitation risk is supported from exports then the decision to patent abroad is intensified. Higher exports from source to destination country imply higher impact of imitation risk in the destination country on patenting abroad. In particular where the imitation risk has a positive impact on the decision to patent in a foreign country, the impact will be even more positive the higher the level of exports. This result is for the full sample of countries and for the group of "small and medium" ones. However, for the group of "big" countries the positive impact is not affected by the interaction. Even though the individual variables, imitation risk and exports, seem to impact the decision to patent abroad, the complementarity (interaction) is not statistically significant suggesting that patenting abroad decision for the group of "big" countries is pursued for other reasons than protecting exports.

Business cycle impact is statistically significant and positive verifying the argument of Geroski and Walters (1995) for the pro-cyclical behavior of patenting. Finally, the counter intuitive sign of the IPR regime in the destination country demands further investigation.

Finally, as more non–OECD countries and emerging economies (e.g. the BRICS[6], other Latin American countries) are increasingly integrated into the world economy and more patent data are available future research could advance our understanding of how international patenting strategy calibrates with international trade dynamics. Furthermore, as GVCs' role become a dominant feature of world trade, international organizations will provide complete data series which could be used to empirically investigate their impact on international knowledge diffusion.

[6] Brazil, the Russian Federation, India, People's Republic of China and South Africa.

References

Acemoglu, D., Linn, J., 2004. Market size in innovation: theory and evidence from the pharmaceutical industry. Q. J. Econ. 119 (3), 1049–1090.
Anderson, J.E., 1979. A theoretical foundation for the gravity equation. Am. Econ. Rev. 106–116.
Archibugi, D., Coco, A., 2005. Measuring technological capabilities at the country level: a survey and a menu for choice. Res. Policy 34 (2), 175–194.
Archontakis, F., Varsakelis, N., 2011. U.S. patents abroad: does gravity matter? J. Technol. Transfer. 36 (4), 404–416.
Arrow, K.J., 1962. Economic welfare and the allocation of resources to invention. In: Nelson, R.R. (Ed.), The Rate and Direction of Economic Activity. Princeton University Press, N.Y.
Baltagi, B.H., 2001. Econometric Analysis of Panel Data. second ed. John Wiley and Sons, Chichester, UK.
Beattie, A. (2012) "A new World of Royalties", Financial Times, 2012 (24 September).
Bloom, N., Van Reenen, J., 2002. Patents, real options and firm performance. Econ. J. 112 (478), C97–C116.
Bosworth, D.L., 1984. Foreign patent flows to and from the United Kingdom. Res. Policy 13 (2), 115–124.
Cameron, C.A., Trivedi, P., 1998. Regression Analysis of Count Data. Cambridge University Press, New York.
Choi, T.Y., Budny, J., Wank, N., 2004. Intellectual property management: a knowledge supply chain perspective. Bus. Horiz. 47 (1), 37–44.
Co, C.Y., 2004. Do patent rights regimes matter? Rev. Int. Econ. 12 (3), 359–373.
Cohen, W., Levin, R., 1989. Empirical studies of innovation and market structure. In: Schmalensee, R., Willig, R. (Eds.), Handbook of Industrial Organization II. North-Holland, Elsevier, pp. 1059–1107.
Dosi, G., Pavitt, K., Soete, L., 1990. The Economics of Technical Change and International Trade. Harvester Wheatsheaf, Hertforshire.
Drivas, K., Economidou, C., 2014. Is geographic nearness important for trading ideas? Evidence from the US. J. Technol. Transf. 40, 1–34.
Eaton, J., Kortum, S., 1996. Trade in ideas: patenting and productivity in the OECD. J. Int. Econ. 40, 251–278.
Eaton, J., Kortum, S., 1999. International technology diffusion: theory and measurement. Int. Econ. Rev. 40 (3), 537–570.
Egger, P., 2000. A note on the proper econometric specification of the gravity equation. Econ. Lett. 66 (1), 25–31.
Ernst, H., Legler, S., Lichtenthaler, U., 2010. Determinants of patent value: insights from a simulation analysis. Technol. Forecast. Soc. Chang. 77 (1), 1–19.
Geroski, P.A., Walters, C.F., 1995. Innovative activity over the business cycle. Econ. J. 105, 916–928.
Ghemawat, P., & De La Mata, T. (2015). Globalization and Gravity. Unpublished working paper.

Ginarte, J.C., Park, W.G., 1997. Determinants of patents rights: a cross-national study. Res. Policy 26, 283–301.
Goniadis, I., Varsakelis, N.C., 2012. Factors affecting patentees to start-up new venture: evidence from Greece. Int. J. Entrep. Behav. Res. 18 (5), 544–558.
Greene, W., 2003. Econometric Analysis. fifth ed. Prentice Hall, NJ.
Griliches, Z., 1979. Issues in assessing the contribution of research and development to productivity growth. Bell J. Econ. 10 (1), 92–116.
Griliches, Z., 1990. Patent statistics as economic indicators: a survey. J. Econ. Lit. 28, 1661–1707.
Guellec, D., van Pottelsberghe de la Potterie, B., 2001. The internationalisation of technology analysed with patent data. Res. Policy 30, 1253–1266.
Hall, B.H., 2004. Exploring the patent explosion. J. Technol. Transf. 30 (1-2), 35–48.
Hall, J., Matos, S., Silvestre, B., Martin, M., 2011. Managing technological and social uncertainties of innovation: the evolution of Brazilian energy and agriculture. Technol. Forecast. Soc. Chang. 78 (7), 1147–1157.
Hall, R., Andriani, P., 1998. Analysing intangible resources and managing knowledge in a supply chain context. Eur. Manag. J. 16 (6), 685–697.
Harhoff, D., Hoisl, K., Reichl, B., Van Pottelsberghe de la Potterie, B., 2007. Patent validation at the country level — the role of fees and translation costs. CEPR Discussion Paper No. DP6565 Available at SSRN:. http://ssrn.com/abstract=1140092.
Hirschberg, J., Lye, J., 2005. Interactions in Regressions, Research Paper no. 952, Department of Economics. The University of Melbourne, Melbourne.
Hirschberg, J., Lye, J., 2010. A reinterpretation of interactions in regressions. Appl. Econ. Lett. 17 (5), 427–430.
Ivus, O., 2010. Do stronger patent rights raise high-tech exports to the developing world? J. Int. Econ. 81, 38–47.
Khan, M., Dernis, H., 2006. Global overview of innovative activities from the patent indicators perspective. OECD Science, Technology and Industry Working Papers, 2006/3. OECD Publishing.
Leamer, E., Levinsohn, J., 1995. International trade theory: the evidence. In: Grossman, G., Rogoff, K. (Eds.), Handbook of International Economics vol. 3. Elsevier, Amsterdam.
Léger, A., 2007. Intellectual property rights and innovation around the world: evidence from panel data. Disc. Paper 696. DIW, Berlin.
Maskus, K.E., Penurbarti, M., 1995. How trade-related are intellectual property rights? J. Int. Econ. 39, 227–248.
Mátyás, L., 1997. Proper econometric specification of the gravity model. World Econ. 20 (3), 363–368.
McCalman, P., 2001. Reaping what you saw: an empirical analysis of patent harmonization. J. Int. Econ. 55, 161–186.
McCalman, P., 2005. Who enjoys TRIPs abroad? An empirical analysis of intellectual property rights in the Uruguay round. Can. J. Econ. 38, 574–603.
OECD (2001)."Using patent counts for cross-country comparisons of technology output", paper drafted by H. Dernis, D. Guellec and B. van Pottelsberghe de la Potterie. The paper is an extract from STI Review 27. Online at http://www.oecd.org/dataoecd/26/11/21682515.pdf
OECD, 2014. Global Value Chains: Challenges, Opportunities and Implications for Policy. OECD, WTO and the World Bank Group.
OECD, 2016. International comparisons. Main Science and Technology Indicators vol. 2015 (2). OECD Publishing. http://dx.doi.org/10.1787/msti-v2015-2-5-en.
Paci, R., Sassu, A., Usai, S., 1997. International patenting and national technological specialization. Technovation 17 (1), 25–38.
Pakes, A., Griliches, Z., 1980. Patents and R&D at the firm level: a first report. Econ. Lett. 5 (4), 377–381.
Petrick, I.J., Echols, A.E., 2004. Technology roadmapping in review: a tool for making sustainable new product development decisions. Technol. Forecast. Soc. Chang. 71 (1), 81–100.
Picci, L., 2010. The internationalization of inventive activity: a gravity model using patent data. Res. Policy 39 (8), 1070–1081.
Putnam, J., 1996. The Value of International Patent Protection. (Ph.D. Thesis). Yale University.
Rafiquzzaman, M., 2002. Impact of patent rights on international trade: evidence from Canada. Can. J. Econ. 35, 307–330.
Rapp, R.T., Rozek, R.P., 1990. Benefits and costs of intellectual property protection in developing countries. J. World Trade 24 (5), 75–102.
Rose, A.K., 2004. Do we really know that the WTO increases trade? Am. Econ. Rev. 94 (1), 98–114.
Schneider, P.H., 2005. International trade, economic growth and intellectual property rights: a panel data study of developed and developing countries. J. Dev. Econ. 78, 529–547.
Smith, P.J., 1999. Are weak patent rights a barrier to US exports? J. Int. Econ. 48, 151–177.
Smith, P.J., 2001. How do foreign patent rights affect US exports, affiliate sales, and licenses? J. Int. Econ. 55, 411–439.
Teece, D.J., 2004. Technology and technology transfer: mansfieldian inspirations and subsequent developments. J. Technol. Transf. 30 (1-2), 17–33.
Tinbergen, J., 1962. The World Economy. Suggestions for an International Economic Policy. Twentieth Century Fund, New York.
Ulku, H., 2007. R&D, innovation and output: evidence from OECD and non-OECD countries. Appl. Econ. 39 (3), 291–307.
Van Pottelsberghe de la Potterie, B., de Rassenfosse, G., 2008. Policymakers and the R&D — patent relationship. Intereconomics 43 (6), 377–380.
Watanabe, C., Tsuji, Y.S., Griffy-Brown, C., 2001. Patent statistics: deciphering a 'real' versus a 'pseudo' proxy of innovation. Technovation 21, 783–790.
Yang, C.-H., Kuo, N.-F., 2008. Trade-related influences, foreign intellectual property rights and outbound international patenting. Res. Policy 37 (3), 446–459.

Dr Nikos C. Varsakelis is Associate Professor and Vice-Rector of Finance at the Aristotle University of Thessaloniki. His research interests focus in the fields of Industrial and Technology Policy. In the past he has served as National Expert in the European Commission and as a research project manager in national and international programmes. His research has appeared in international journals such as: Research Policy, Technovation, the Journal of Technology Transfer, Transnational Corporations, Atlantic Economic Journal.

Dr Fragiskos Archontakis holds an MA in Economics and Econometrics from the University of Manchester and a PhD(Econ) from the European University Institute, Florence. Prior to joining IHU, Fragiskos was employed among others by the European Commission, the Spanish High Research Council (CSIC), the University of Alicante, RAND Europe and the University of Athens. His research has appeared in international journals such as: Research Policy, Scientometrics, Journal of Sports Economics, Statistical Methods and Applications, the Journal of Technology Transfer.