The Internationalization of Inventive Activity: A Gravity Model Using Patent Data

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15 October 2009

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This version: October 2009

Abstract

This paper discusses the extent and the determinants of the internationalization of European inventive activity, between 1990 and 2005, using an innovative method to treat the information contained in the European Patent Office's Patstat database. We introduce a new set of indicators measuring internationalized patent applications that are fully coherent with the principle of fractional counting. The observed level of internationalization of inventive activities, while being rather low, has steadily increased over time.

The amount of collaboration between actors residing in different countries is assessed by means of a gravity model. The amount of bilateral collaboration is positively affected by the presence of a common language, a common border and by more similar cultural characteristics. International collaboration is negatively affected by distance, with estimated elasticities that are significantly smaller than the ones that characterize international trade.

Keywords: Internationalization; R&D; Patent statistics; Gravity model.

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1. Introduction

Almost all contemporary products are the result of some form of international collaboration and trade. A cell phone is a bundle of many components that, almost invariably, are produced in different countries. Raw materials are traded to such an extent that anything containing plastic or metal components is also very likely to be the result of international trade. As for services, the current lore on international outsourcing of back-office routines indicates that internationalization, while not being preponderant, is certainly increasing.

Innovative activities, on the other hand, are largely the result of efforts which take place in single countries. Almost twenty years ago, considering the patenting activities of a sample of big US firms, Patel and Pavitt (1991) observed that "in most cases, the(ir) technological activities […] are concentrated in their home country", and concluded that "despite being a critical resource in the global competition and performance of both companies and countries […] the production of technology remains far from globalised." Since then, globalization has certainly made inroads into this domain, thanks to robust increases in international collaboration of various types, to the off-shoring of many R&D labs, and to advances in the protection and trade of intellectual property rights. However, as we will demonstrate, it is still true that innovative activities are predominantly national in scope.

This paper aims to identify the determinants of the intensity of international collaboration in inventive activities, and what they tell us about why the degree of internationalization of innovative activities is still relatively low. To address this issue, several researchers have exploited in various ways the information contained in patent data (see, among others, Patel and Pavitt, 1991; Patel and Vega, 1999, and Le Bas and Serra, 2002). The research presented here also uses patents data. While most previous studies have considered the patent portfolios of (multinational) firms, here we attribute patents to countries, by exploiting the fact that patents data provide separate information on the nationality of the inventors and of the applicants. If a given patent involves only people and organizations residing in the same country, we define it as "national". If, on the other hand, at least one inventor or one applicant resides in a country different from that of the others, then we call the patent "international". Moreover, the presence of an important functional distinction between inventors and applicants allows us to define and analyze different measures of internationalization.

We adopt a methodology to compute patent statistics focusing on all applications claiming the right to priority that are filed at any one of the EU27 national patent offices, the European Patent Office (EPO), the United States Patent and Trade Mark Office (USPTO), or the Japanese patent office. Applications claiming the right to priority are those that are filed at a particular patent office for the first time. Focusing on them only is a possibility only recently made available, thanks to the Patstat database (European Patent Office, 2009a and 2009b), which is the source of our data. The methodology used allows to control for the presence of the "home bias effect" (the tendency of residents of a country to file patent applications in their country's patent office), and is fully documented in De Rassenfosse et al. (2009).

We adopt a gravity model to study the determinants of the intensity of collaboration between pairs of countries. The gravity model ("one of the more successful empirical models in economics", Frankel and Rose, 2002) has had remarkable success in explaining bilateral trade flows. It describes trade between two countries as increasing in their economic size, and as decreasing in their distance (hence the resemblance with Newton's gravity law). This model has been given several theoretical rationalizations, the first proposed by Anderson (1979). Disdier and Head (2008) performed a meta-analysis on 103 papers applying the gravity model and report a mean elasticity of bilateral trade with respect to distance of 0.9, "indicating that, on average, bilateral trade is nearly inversely proportionate to distance". They also show that distance effects "decreased slightly between 1870 and 1950 and then began to rise". Besides the negative effect of distance, other variables have generally been found to positively determine bilateral trade, such as the presence of a common border, a common language, a common market, a common currency area (for the latter, see Rose, 2000, and Baldwin, 2006), and a higher level of mutual trust (Guiso et al., 2009) The gravity model has been also applied to describe relations other than traditional trade in goods. In particular, distance effects have been found in the trade of services (Ceglowski, 2006, and Kimura and Lee, 2006), trade through the Internet (Blum and Goldfarb, 2006), knowledge flows through patent citations (Peri, 2005), immigration flows (for a recent example, see Lewer and Van den Berg, 2007), and also in fields outside economics.

Our approach appears to have only one published antecedent, the paper of Guellec and van Pottelsberghe de la Potterie (2001), who use measures of R&D internationalization similar to ours, which we introduce in the next section. One dimension in which this paper is innovative is in its treatment of patent information. We dedicate Section 3 to a description of the data. In Section 4, we illustrate the empirical model and the main results, which we discuss in Section 5.

2. Measures of internationalization

To present our measures of internationalization, we first briefly review the familiar concept of fractional counting of patents (see for example Dernis et al., 2001). To help make the discussion as easy to follow as possible, we use a simple fictitious example. We consider three countries, United Stated (US), France (FR), and Germany (DE), that in a given year produce a total of P=3 patents. Column I in Table 1 indicates the nationality of the inventors and applicants that contributed to these three inventions.

Table 1 about here

In order to assign patents to countries, two alternative criteria may be chosen: either according to the nationality of the applicant(s), or of the inventor(s). The former defines the "applicant criterion" and the latter the "inventor criterion". Whenever an application has more than one inventor or applicant, some of them coming from different countries, patent assignment is carried out by resorting to fractional counts. So, for example, patent n. 1 counts as ½ German and ½ American according to the applicant criterion, and ½ American, ¼ German and ¼ French according to the inventor criterion.

Let us call $Inv_{i,p}$ the fraction of patent *p* attributed to country *i* according to the inventor criterion, and $App_{i,p}$ the analogous measure according to the applicant criterion. Column II and III of Table 1 report these measures for the three patents. For each patent, the sum of all the country's contribution according to the inventor criterion has to be equal to 1: for each patent, $Inv_{US,p} + Inv_{DE,p} + Inv_{FR,p} = 1$, where the first subscript indicates the country, and the second the patent (for clarity we use the mnemonic symbol of the relevant country, instead of *i*, and we omit a time subscript that should be present). These sums are indicated in Column IV of Table 1.

The total fractional assignment of the three patents to each country is simply equal to the sum of the individual assignments:

(1) $$Inv_i = \sum_{p=1}^{P} Inv_{ip}$$

and:

$$(1') \quad App_i = \sum_{p=1}^{P} App_{ip}$$

They are reported in the last two rows of Table 1. For example, Germany produced a total of 0.75 patents according to the inventor criterion, and of 0.5 patents according to the applicant criterion.

Having defined the concept of fractional counting, we proceed to develop useful measures to express the degree of collaboration in producing patents between (the agents residing in) two countries. Again, we discuss them using the fictitious example of Table 1. We define three concepts of internationalization of a given patent:

Inventor-Applicant internationalization (InvApp): Whenever a patent has (at least) one inventor and one applicant that come from different countries. All three patents of the example belong to this type.

Inventor internationalization (in short, InvInv): Whenever a patent has at least two inventors resident in different countries. All three patents in our example display this type of internationalization.

Applicant internationalization (AppApp): Whenever a patent has at least two applicants resident in different countries. Patent 1 and 2, but not patent 3, display this type of internationalization.

InvApp is the more general type of internationalization. In fact, the presence of InvInv implies InvApp – if there are two inventors from different countries, then it is also necessarily true that one inventor and one applicant are from different countries. Similarly, AppApp implies InvApp. All international patents are necessarily of the InvApp type, and possibly also of the InvInv and/or of the AppApp type.

There are some forms of international inventive effort that our measures may fail to detect. Consider a multinational corporation (from country A) acquiring a firm abroad (in country B) with a long record of patenting its innovations at country B's patent office. Our measures would not define this activity as "international", unless at least one inventor is from outside country B, possibly from the headquarters in country A. However, it may in fact be appropriate not to consider the case as an example of internationalization of *inventive* activity (possibly, as opposed to a case of internationalization of *productive* activity), considering that these inventions are not necessarily shared with headquarters.[2]

[2] I thank an anonymous referee for suggesting this possibility.

A further case of interest applies when a firm owns a R&D unit in a foreign country, producing an invention with the help of inventors that are all resident in that same location. If, moreover, the applicant of the filing is the foreign subsidiary (instead of the firm's headquarters), then all the applicants and the inventors would be from the same country and therefore the patent application, according to our taxonomy, would fall into the "national" category. However, multinational corporations tend to file through their headquarters (a fact that is also supported by evidence that we present in Table 3 below). Moreover, even when they file through a foreign subsidiary, given the international scope of the firm, it would be likely that at least one inventor is from another country, and also the filing could be done jointly with another subsidiary in a different country, so that the patent would be classified as international.

Another case of internationalization that would go undetected is when two firms from different countries constitute a joint R&D effort in one of the two countries, or in a third country, and produce an invention where all the inventors are residents of the country where the jointly-owned firm is registered. Arguably, there should not be very many of these cases.

Having discussed the general concepts of Inventor, Applicant, and Inventor-Applicant internationalization, we now proceed to define the related measures, starting with the first one. For each patent, the strength of the relation between inventors in country *i* and *j* is expressed as the product of the attribution of that patent to the two countries:

$$(2) \quad InvInv_{ijp} = Inv_{ip} \cdot Inv_{jp}$$

This measure attributes a greater weight to collaborations where the two countries have more similar weights. So, for example, the collaboration between the US and France is equal to ½ · ¼ = $^1/_8$ in patent n. 1 (where there are 1 French and 2 American inventors) and to ½ · ½ in patent 3 (where the total number of inventors, 2, is equally divided between the US and France. In fact, if *i* is different from *j*, $0 \leq InvInv_{ijp} \leq 1/4$, where the upper bound is reached when the total number of inventors is equally divided between two countries, and the lower limit applies when a patent is national.

The aggregate strength of the relation between the inventors of two countries is defined as the sum of the above, over all patents:

3) $$InvInv_{ij} = \sum_{p=1}^{P} InvInv_{ijp}$$

Below, we report the values for all the combinations of the three patents in Table 1, where for clarity, instead of the indexes *i* and *j*, the acronyms of the countries are employed.

$$InvInv_{US,US} = 0.5 \cdot 0.5 + 0 \cdot 0 + 0.5 \cdot 0.5 = 0.5$$

$$InvInv_{US,DE} = 0.5 \cdot 0.25 + 0 \cdot 0.5 + 0 \cdot 0.5 = 0.125$$

$$InvInv_{US,FR} = 0.5 \cdot 0.25 + 0 \cdot 0 + 0.5 \cdot 0.5 = 0.375$$

The top part of Table 2 shows the values of these interactions for all three cases. Note that $Inv_{ij} = Inv_{ji}$ (the order of the countries is irrelevant). Using (1), it is easy to see that:

(4) $$\sum_{i=1}^{N} InvInv_{ij} = Inv_j \quad \text{and} \quad \sum_{j=1}^{N} InvInv_{ij} = Inv_i$$

For example, as predicted by (4):

$$InvInv_{US,US} + InvInv_{US,DE} + InvInv_{US,FR} = 0.5 + 0.125 + 0.375 = 1 = Inv_{US}$$

These sums are reported for all three countries in the last column and in the last rows of the top part of Table 2, and correspond to the values reported in Table 1. They show that the country patent portfolio, assigned according to the inventor criterion, may be expressed as a sum of pairwise measures of country inventive collaboration ($InvInv_{ij}$).

The measure of applicant internationalization is constructed along the same lines, and the following formulae hold:

(2') $$AppApp_{ijp} = App_{ip} \cdot App_{jp}$$

(3') $$AppApp_{ij} = \sum_{p=1}^{P} AppApp_{ijp}$$

(4') $$\sum_{i=1}^{N} AppApp_{ij} = App_j \quad \text{and} \quad \sum_{j=1}^{N} AppApp_{ij} = App_i$$

All computations for this case are shown in the middle part of Table 2. Note that $App_{ij} = App_{ji}$ (again, the order of the countries is irrelevant). Equation (4') allows us to express a country patent portfolio, according to the applicant criterion, as a sum of interactions between applicants in different countries. The values reported in the last column and row of the middle part of Table 2 correspond to those of Table 1.

We construct a measure of Inventor-Applicant internationalization similarly. The strength of the collaboration between inventors in country *i* and applicants in country *j*, for a single patent *p*, is defined as:

(5) $InvApp_{ijp} = Inv_{ip} \cdot App_{jp}$

Summing over patents provides a measure of the strength of the overall collaboration between country *i* inventors and country *j* applicants:

(6) $InvApp_{ij} = \sum_{p=1}^{P} InvApp_{ijp}$

These measures aggregate to the patent attributed to a country either according to the inventor, or to the applicant criterion, depending on whether the summation is over *i*, or over *j*:

(7) $\sum_{j=1}^{N} InvApp_{ij} = Inv_i$

(7') $\sum_{i=1}^{N} InvApp_{ij} = App_j$

The bottom part of Table 2 indicates all computations for our fictitious example. Note that $InvApp_{ij}$ generally differs from $InvApp_{ji}$.

The quantities defined in (3), (3') and (6) are the three measures of internationalization of innovative activities that we will assess in Section 4 using a gravity model. In the next section, in order to provide a first description of the degree of internationalization, we will use measures of internationalization that are *relative* to the total number of patent applications. Starting from (3) and (3'), the necessary computations are straightforward:

(8) $InvInv_{ij|i} = Inv_{ij} / Inv_i$

and

(8') $AppApp_{ij|i} = App_{ij} / App_i$

where $\sum_{j=1}^{N} InvInv_{ij|i} = 1$ and $\sum_{j=1}^{N} AppApp_{ij|i} = 1$.

In the case of (6), we can compute two relative measures, depending on whether the normalization is carried out with respect to the inventors of country *i*, or to the applicants of country *j*:

(9) $InvApp_{ij|i} = InvApp_{ij} / Inv_i$

(9') $InvApp_{ij|j} = InvApp_{ij} / App_j$

where $\sum_{j=1}^{N} InvApp_{ij|i} = 1$ and $\sum_{i=1}^{N} InvApp_{ij|j} = 1$.

Our metrics of relative internationalization have similarities with those of Guellec and van Pottelsberghe de la Potterie (2001), who adopt three measures that they call SHAI, SHIA, and SHII. The first one is similar to our (9), the second to (9'), and the third to (8). Our measure (8') has no analogue in their paper. Our measures have three main advantages on others that have been employed in the literature (see also OECD, 2008). First, we use fractional counting so as to count as "more international" those patents where international collaboration is more pronounced. Secondly, the appropriate use of fractional counting allows to decompose a patent portfolio as a sum of pairwise internationalization linkages, plus a fully national component (equations 4, 4', 7 and 7'). Thirdly, contemplating all possible types of internationalization, as they may be detected using patent data, allows to compute alternative measures whose contrast may be informative.

3. The data

We consider patent applications, not granted patents. This choice, besides being a common practice in the literature, has the advantage of allowing an analysis of more recent data, considering that several years typically elapse between the filing and the granting of a patent. The source of the data is the Patstat database, based on the EPO's "master bibliographic database DocDB" (European Patent Office, 2009a and 2009b), and covers data from more than 80 patent offices. An important and innovative characteristic of Patstat is that it allows the identification of patent applications that claim the right to priority (that is, it permits us to distinguish between multiple applications for the same inventions in several patent offices). We take full advantage of this characteristic and we only consider "priority" applications.

Most studies on patents only use information from a single patent office. Given our focus on the internationalization of patents, this approach would not be viable, because the presence of the "home bias effect" would vitiate any study based on a single, even if very important, national patent office. For this reason, we consider applications filed in any one of the patent offices of a member state of the European Union (in its current configuration of 27 States, EU27), at the EPO, the USPTO and the Japanese Patent Office. Guellec and van Pottelsberghe de la Potterie (2001) and OECD (2008) focus their attention on the filings to the EPO only, a strategy that rests on its continental scope. However, such a choice also is questionable, for two reasons. First, many European patents never reach the EPO as priority filings, or as successive applications. Secondly, the decision to file to the EPO is influenced by factors that are country-dependent. In particular, agents from smaller countries, which have been members of the EPO for longer and whose national patent offices have higher filing fees, have a higher propensity to use that institution (De Rassenfosse and van Pottelsberghe de la Potterie, 2007).The two reasons together imply that only focusing on the EPO may induce biased estimates. Using data from the EPO only (or from one or few national patent offices, as in the triadic approach – see Dernis and Khan, 2004) was also a matter of convenience and, until some time ago, it was almost unavoidable. With the availability of the Patstat database, better alternatives have become available.

The Patstat database, however, while being very innovative, is still in its infancy, and the data of each patent office require careful analysis and often ad-hoc treatment in order to be included. The choice of the patent offices to be included was made considering a trade-off between considering more offices, and the high incremental costs to be incurred to check the quality of the data and to make any corrections that may be necessary. The methodology employed is fully documented in de Rassenfosse et al (2009). Out of all applications filed at the selected patent offices between 1990 and 2005 (a total of 8,260,081), 224,911 are international according to our classification.

Table 3 about here

Table 3 documents some relevant characteristic of these international patents. We consider first its last line, that reports the frequency of the types of internationalization. About 56% of the international patents do not display any other type of internationalization besides the InvApp (only) type. The other international patents also manifest some other type of internationalization. The most frequent occurrence is of patents that are both of the InvApp and of the InvInv type (about 31% of the total). The cases involving AppApp internationalization are relatively infrequent (last two columns).

Next, we ask ourselves about the nature of the applicants. Unfortunately, besides reporting their names, patent statistics tell us nothing about their nature – be them national or multinational firms, universities, etc. The only way to find out is to carry out individual searches, a task that would obviously be too demanding if it were to be conducted on the whole group of about 225 thousand international patent applications. As a compromise, we selected selected a stratified random sample of 1,000 units, with proportional allocation in the year variable. For each one of them, we determined (using Internet searches and, in a few cases of doubt, the Amadeus business registry) the type of applicant(s), according to the following classification.

"Multinational Enterprises" (MNEs) are firms that control at least one production unit in a country different from where they are based. We do not distinguish between headquarters and those subsidiaries that may be present in the same country as heaquarters (both are indicated as HQ). “Subsidiaries” (SUB) are firms controlled by MNEs and located in a country different from that of the headquarters. "Firms" are all firms that are not (part of) a MNE. "Universities" include all universities, and "Public research institutes" are research institutions that are primarily financed by public administrations (in all cases considered, they are also publicly owned, and clearly public in nature).

The rest of Table 3 refers to results computed on the sample of 1000 patents. The last but one row reports the type of internationalization of the patent applications contained in the sample, with differences with respect to the population total that are due to sampling error. Each column reports the relative frequencies of the type of applicant conditional on the type of internationalization (note that the sum of the percentages by columns is always equal to 100%). Around 84% of the patents that are only of the InvApp type (and not of the InvInv and/or AppApp type) are the result of the activity of MNE. In most cases, MNE file through their headquarters, the only exception being for patents of the InvApp and AppApp type, that, implying collaboration of firms in distint countries, not surprisingly involve a higher number of MNE foreign subsidiaries. In general, relatively few of the applications are carried out by firms (or other entities) that are not (part of) MNE. Applications from MNE headquarters are of decreasing importance as we move in the table from left to right. A Pearson χ^2 test shows that the relative importance of each type of applicant is not independent of the type of internationalization, implying that the differences that we have commented upon, as a whole, are statistically significant.

To assess the overall degree of internationalization of inventive activity, we compute the relative measures of internationalization defined by Equations 8, 8', 9 and 9' of the previous section, for EU27, the United States and Japan, on all applications filed between 1990 until 2005. The data for EU27 are computed as a weighted average of the country level data, with weights equal to the relative size of patent portfolio of each country (computed according to the inventor criterion). The results are shown in Figure 1.

Figure 1 about here

All measures indicate a degree of internationalization that is still rather modest, even though it has increased steadily since the early 1990s. The European country average indicates the highest level of internationalization, around 8% for InvApp internationalization at the end of the period. The United States showed a marked increase in internationalization in the 1990s, with levels roughly constant in the last few years. Japan has a very low share of international patents, reflecting both a reduced degree of internationalization of Japanese R&D, and a very high propensity to patent of Japanese entities.

We also observe important differences among the four alternative metrics, with the two relative measures of inventor-applicant internationalization being well above the others. The first of the two (indicated in the Figure as InvApp | Inv) refers to patents that have national inventors and extra-national applicants, and InvApp | App the opposite. Let's focus on the case of Europe. The typical case accounted for by the InvApp | Inv measure is the one of a foreign MNE owning an R&D lab in a European country and filing the patents produced there through its headquarters in the home country. The fact that the first measure is higher than the second indicates the relatively high importance of foreing applicants in European inventive activity. The opposite happens for the United States, indicating a pre-eminence of US applicants abroad.

Overall, these data allow us to declare that the degree of "globalization" in the production of technology, to refer again to the work of Patel and Pavitt (1991), has increased since the time when they wrote, but is still rather low in relative terms.

4. A gravity model of international inventive activity

The basic model that we estimate is the following:

$$\ln(INT_{ijt}) = \beta_0 + \beta_1 \ln(A_{it}) + \beta_2 \ln(A_{jt}) + \beta_3 \ln(dist_{ij}) + \lambda L_{ijt} + \beta_4 D_{it} + \beta_5 D_{jt} + \varepsilon_{ijt}$$

where *ln* is the natural log, INT is one of the three bilateral measures of internationalization of inventive activity (equations 3, 3' or 6), *A* is the "inventive mass" of country *i or j*, that we proxy it with $Inv_{i\ or\ j}$ and $App_{i\ or\ j}$ (the total country patent portfolio, see equations 1 and 1'). *Dist* is the distance between the capital cities of pairs of countries (computed with the great circle formula) and *L* is a vector of other conditioning variables. It includes *Border,* a dummy for the presence of common borders, dummies for the inclusion in the European Union (*Eu Union*) and in the European Monetary Union (*Euro Zone*), and *Com lang*, a variable representing the presence of a common language (see the Appendix for a description, and data sources, of this variable and of the following ones). In *L* we also include *Tech*, an indicator of pairwise "inventive proximity", computed as the correlation between two vectors, one for each country, formed by the number of patent priority applications in each of the eight technology classes according to the International Patent Classification.

It is quite likely that the costs of travel alone are not able to explain any effect that physical distance may have – just as they do not fully explain the negative effect of distance on international trade. It could well be that what really matters is a broad concept of cultural distance. The success of R&D activities rests upon the smooth functioning of many tasks that are not limited to research activities proper, but also include, for example, the building of the necessary infrastructure and the protection of the intellectual assets that are eventually produced. Since the necessary mutual understanding among all parties involved may be guaranteed only in part through contractual arrangements, tacit agreements end up playing an important role. Arguably, the further away two cultures are, the more difficult it is for tacit agreements to be honored, and the more problematic is collaboration.[3] In order to assess the role of cultural differences, we include among the regressors some variables that should capture these effects.

We consider first a survey-based quantification on mutual trust between countries, *Trust,* that originates from one of the questions contained in the Eurobarometer survey. The variable *Lang sim* describes language similarity, and takes higher values for languages that share more common "branches". Note that *Lang sim* is certainly correlated with *Com lang*, but it conveys different information. *Com lang* is meant to capture ease of communication (commonality of the language spoken in a couple of countries), while *Lang sim* is meant to proxy cultural proximity, imagining that persons whose languages share common roots also indicate the presence of more similar cultural traits. *Religion sim* is computed as the probability that two persons in different countries share the same broad religious group. *Somatic dist* is based on the weighted average of four distinct somatic characteristics. These last two variables are available only for a group of 14 countries (all of them current member of the European Union, plus Norway – See the Appendix).

We expect the degree of protection of Intellectual Property Rights (IPR_{ij}) (the index of patent rights of Park, 2008) to influence choices of internationalization. On the one hand, better IPR protection favors international collaboration, since it limits the possibility that ideas, by travelling the distance, get stolen. However, facing a deficient IPR protection at home may induce important firms to locate their R&D activities in countries affording better protection. Also, inventors in a country affording poor IPR protection may have a further stimulus to look for employment in the R&D labs of multinational corporation, that can shield themselves better by patenting their inventions through their headquarters. Adding to the subtlety of the issue, we should consider that the relation between IPR protection and inventive activities is endogenous, because multinational corporations are likely to lobby for stronger IPR, both at home and, depending on their degree of internationalization, abroad.

We also consider measures of Foreign Direct Investment (FDI). We use a set of eight variables, expressing, for each country in a pair, flows or stock, inward or outward.

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[3] A survey of senior executives representing a wide range of industries, carried out by The Economist Intelligence Unit (2007), indicated "cultural differences" as the third most important risk to developing global innovation networks (the first and the second one being, respectively, theft of intellectual property, and loss of control over innovation processes).

The source of the data, expressed at current US Dollars[4] at current prices and exchange rates, is UNCTAD (2009). These measures represent FDI regardless of its motives, and we should expect that only a small component is dedicated to R&D activities abroad. Moreover, the measures are aggregate also in the sense that no distinction on the recipient or source country is made.

Last, we include a series of country-specific fixed effects, one for each country and year – the two *D* variables. This specification is quite flexible, including all possible fixed effects, short of estimating a Fixed-Effects panel model. The presence of a year dummy interacted with the country dummies is coherent with the discussion in Baldwin and Taglioni (2006). We estimate the basic model using data on pairwise collaboration between countries that are directly computed from our set of about 225 thousand international patents. We compute all bilateral ties for a total of 42 countries (see the Appendix), and we also consider a subgroup of 14 countries, all of them European, for which the *Trust* and *Somatic dist* variables are available. The maximum number of pairwise linkages is $N \cdot (N-1) \cdot T$, where *N* is the number of countries (either 42 or 14), and *T* the number of years under consideration (16, from 1990 until 2005). The actual number of observations used will in fact be sensibly smaller, due to the presence of many zero pairwise linkages, that the logarithmic transformation transforms into missing values. The presence of a limited number of further missing values is due to the incomplete coverage of the FDI data.

We obtain our main results using the OLS estimator. Santos Silva and Tenreyro (2006) argue that the nature of the estimation problem in a gravity model may induce a form of heteroskedasticity of the error term that, due to the log transformation of the data, leads to the inconsistency of the OLS estimator. They argue that a Poisson estimator is not prone to the problem (see also Martínez-Zarzoso et al., 2009, for a critical appraisal of the suggested approach). Estimates obtained using this method, that we report in Table A.1 in the Appendix, do not differ sensibly from the OLS results. In commenting them, we will indicate the few instances when the two methods lead to different conclusions.

Table 4 shows the estimates of the gravity model for the three types of internationalizations. In interpreting the results, note that same variables indexed *i* and *j* will have estimated coefficients that are numerically the same when explaining InvInv or

[4] The nature of the dummy variables included – see below – makes unnecessary expressing these quantities at constant prices.

AppApp internationalization, because the related measures are symmetric. We report these estimates only once (columns from 3 to 6). On the other hand, $InvApp_{ij} \neq InvApp_{ji}$ – see the discussion in Section 2 – so that variables indexed *i* and *j* will not have the same impact on the more general measure of internationalization.

Odd-numbered columns are on the whole group of 42 countries, while even-numbered columns show the results for the group of 14 European countries[5]. Sharing a common border and a common language has a significantly positive effect on all types of international inventive collaboration. Distance is found to negatively affect international collaboration, with an elasticity that, for the broader group of countries and for InvApp internationalization, is approximately equal to 25%. For all types of internationalization, we find higher estimates when we consider the subset of European countries. Being a member of the European Union, or of the European Monetary Union, also positively affects the level of internationalization. The measure of inventive proximity, *Tech*, positively influences InvApp and InvInv internationalization, while for the infrequent cases of AppApp internationalization the sign of the impact depends on whether we focus on the whole set of countries, or on the smaller subset.

Table 4 about here

The variables expressing cultural distance generally are significant and with the expected sign. *Language sim* has a stronger estimated effect on the larger group of countries. Its effect is estimated to be negative in the case of AppApp internationalization in the subset of European countries. The effect of *Religion sim* if for the most estimated to be positive. *Trust* and *Somatic dist*, available only for the group of European countries, are for the most precisely estimated.

The Poisson estimates indicate that, for the European sample, better IPR protection improves internationalization, in most cases. OLS estimates are contradictory, indicating in one case a *negative* effect of IPR protection. We similarly fail to find significant and unambiguous effects of the FDI variables, again with differences between the responses

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[5] Estimates have also been carried out on the whole set of countries that are currently member of the European Union (without the *Trust* and *Somatic dist* variables), with results that in all cases are similar to the ones obtained for the subgroup of 14 European countries. The results are available from the author.

provided by the two alternative estimators – the Poisson estimator indicating a positive effect of the outbound FDI stock and, on InvInv internationalization, a negative one of the inbound stock.

To appreciate any change in time of the estimates of the distance elasticity, we estimate the gravity model separately for each year, using both estimators, and on both samples. We exclude from the list of regressors IPR_{ij} and the eight variables representing FDI flows and stocks, considering that we found their explanatory power to be limited. The full set of results (available from the author) indicate that, by and large, for most years we find the same results that emerged when pooling the 16 years of observations. In Table 5 we provide a summary of the results. Focusing on the broader concept of internationalization, $InvApp_{ij}$, the yearly estimates of the distance elasticity are significant in between 11 and 14 years, depending on the sample and on the estimation method used.

We adopt a simple device aimed at representing the changes in time of the yearly estimates of the distance elasticity. Using weighted OLS, we estimate a bivariate regression where the independent variable is the set of estimated distance elasticities, a total of 16 of them, and the explanatory variable is time (expressed as years, from 1990 to 2005). The weight of each observation is set equal to each estimated distance elasticity divided by its standard error, so as to give more importance to those coefficients that are estimated with more precision. We carry out this exercise for all types of internationalization, with elasticities obtained using both types of estimators, and on both groups of countries. We report the results in Table 5, where the p-value is of the estimated coefficient of the time variable. The fitted line is then used to compute the predicted distance elasticities for the first and the last year of the period under considerations.

Table 5 about here

When we consider the group of 42 countries, the OLS estimates diminish significantly in time for the broader definition of international collaboration, $InvApp_{ij}$. The Poisson estimates, on the other hand, do not show any significant tendence to either increase or decrease during the period under considerations. Both OLS and Poisson estimates, on the other hand, concord in indicating that distance elasticities have increased in time for InvInv internationalization, and decreased for the infrequent cases of AppApp internationalization. The results of InvApp internationalization change significantly when we obtain the estimated elasticities on the smaller group of European countries (lower part of Table 5). In these cases, unambiguously, we observe yearly estimates of the distance elasticity that are smaller in later years.

5. Discussion

In this paper, we have discussed the extent, and researched the causes of, internationalization of innovative activities, using a dataset on priority patent applications filed at any patent office in the European Union, in the United States and in Japan between 1990 and 2005. We found that the degree of internationalization of innovative activities, while increasing over time, is still relatively limited. Such a lasting "lack of globalization" may come as a surprise, at least if it is observed in the light of the amazing intricacy of the relations that govern today's international division of labor.

R&D internationalization, however, is now more pronounced than it was 20 years ago. Much evidence, both of anecdotal, and of a more systematic nature, indicates that in the more recent years there was an important increase in off-shoring of R&D activities to countries such as China and India, with rationales shifting from the traditional “home-base exploiting” to “home-base expanding” motives. Our data, up to the year 2005, do not detect these changes, that possibly will take some time to manifest themselves in patent statistics.

We stay away from the debate on what exactly are the emerging forms of global R&D efforts. Types of more open innovation, as described in Chesbrough (2003), are quite likely to be part of the story. However, adopting catchphrases to describe complex realities is risky and, in the case at hand, may conduce to confusion between the conceptually distinct ideas of “openness” and “internationalization” of innovative processes[6]. The whole issue, while certainly deserving the attention of researchers, is outside of the scope of our work.

We studied the factors that determine the observed level of internationalization using a gravity model. From our results, it emerges unambiguously that distance negatively

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[6] For example, for some firms, constructing an ecosystem conducive to open models of innovation may be an alternative to more traditional off-shoring of tightly controlled R&D labs. That is, in some cases we may observe more openness leading to less internationalization. Evidence on emerging models of open innovation, mostly seen from the point of view of internationalization, is in OECD (2008).

affects the internationalization of R&D activities, both as expressed by the presence of a border in common between couple of countries and, most importantly, by physical distance, with estimated elasticities that are however sensibly lower than the ones usually found in the literature on international trade. We posited that the physical distance variable could proxy for a broadly defined concept of cultural distance, and in fact we found that variables meant to capture cultural distance are in most cases highly significant. However, these measures do not succeed in explaining the role of physical distance away. Just as in the debate on international trade, we find that physical distance matters in determining the strength of bilateral ties.

Year-by-year estimates of the distance elasticity allowed us to appreciate its changes in time, although with the obvious caveat that the period under consideration, 16 years, is certainly a narrow window for this type of exercise. We find evidence that the impact of distance on InvInv internationalization increased in time. A possible explanation of this finding would be the following. InvInv internationalization represents collaboration of inventors from different countries. Many impediments to international collaboration of various types have decreased over the last decades – think of the lower costs of travel and of telecommunications, and the increased ease with which tools such as videoconferencing permit the transmission of forms of tacit knowledge. These changes are reflected in the overall increase in internationalization that emerges from our data. However, we may argue that, during the same period, the importance of factors related to cultural distances (themselves correlated with physical distance) have remained roughly constant, so that their *relative* importance has increased.

As for the other types of internationalization, and most importantly, for the more general InvApp type, the results depend on the group of countries that we analyze. The relevance of distance on InvApp internationalization may have increased when we observe the whole group of countries (also depending on the estimation method that we use), while we find stronger evidence that it *decreased* if we analyze the subset of European countries. Most cases of InvApp internationalization are the results of the activities of multinational firms abroad, as Table 3 shows. In this result, we may see the integrating effect of the European Union, whose impact is estimated to be positive in most specifications. The European Union is a policy bundle composed of many ingredients, among which we mention the presence of a common regulatory framework, a common market, and an innovation policy that, among other things, explicitly encourages international collaboration within the EU borders. Disentangling these effects, leading to a better understanding of the interaction between public policies and the internationalization of inventive activities, is outside of the scope of the present work.

We also tend to find a positive impact for a single important element of the European policy package, namely, being a member of the Euro Zone. This result is best seen in the light of the debate that followed the contribution of Rose (2000), who found a significant and economically very strong positive effect of currency zones on international trade. Later studies tended to confirm the presence of such an effect, but they significantly reduced its estimated size – see Baldwin (2006).

Regardless of the changes in time that may have occurred, the estimated effect of distance on the internationalization in Europe is a robust conclusion of our work. One of the explicit policy goals of the European Commission is to encourage the formation of a "European research area".[7] We find that innovators in member states "naturally" decide to collaborate sensibly more frequently with like-minded innovators residing in countries that are physically and culturally close, that share a border and a language. Without proper incentives that alleviate the negative effect of distance, this may lead to a cozy integration among neighbors, a situation not necessarily corresponding to the type of "European research area" that policy makers have in mind. For this reason, the role of distance should enter the policy debate.

In Europe, the overall process of integration has reduced many of the impediments to international R&D collaboration. However, a process of integration may also reduce the motivations inducing firms to invest resources to carry out a process of internationalization. Market integration may make it less necessary to set up R&D labs abroad for traditional home-base exploiting motives – for example, there is less need to adapt one's products to foreign markets, if technical requirements are standardized. Also, the stronger protection of IPR that may follow a process of integration, may induce to locate (part) of the innovative process outside of the boundaries of the firms, by relying more on market for technologies, and less on R&D labs abroad.

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[7] See for example the home page of European Commission's DG Research (the Directorate General responsible for Science, Research and Technology), declaring that "European Research, and more specifically the creation of a European Research Area, are now high on the policy agenda in Europe". (http://ec.europa.eu/research/index.cfm?pg=why&lg=en . Last accessed on 15 October 2009).

We fail to find unambiguous evidence of a significant role of IPR protection. The reasons could be many, but our discussion in the previous section suggests that the relationship between the protection of IPR and distinct types of internationalization of inventive activities is not a simple one, so that further work should be done to disentangle it – for example, by developing different measures for different aspects of IPR protection, and by disaggregating measures of internationalization according to some likely important characteristics, such as, the technological field and the type of applicant. We also failed to find an unambiguous effect of FDI, with results that also in part depended on the type of estimator chosen. Using bilateral FDI measures, that are notoriously scanty, would be an appropriate step better understand the nature of the relation. The fact that no obvious pattern emerges from our study, however, to some extent also confirms the relevance of the departure point that we chose for this paper: The internationalization of productive activities (of which FDI mostly talks), and the internationalization of inventive activities, are still two quite distinct sides of the globalization coin.

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Tables

Table 1. Fractional counts of three fictitious patents

I	II			III			IV	
	$Inv_{US,p}$	$Inv_{DE,p}$	$Inv_{FR,p}$	$App_{US,p}$	$App_{DE,p}$	$App_{FR,p}$	$\sum_{i=1}^{N} Inv_{ip}$	$\sum_{i=1}^{N} App_{ip}$
P=1: Inv: DE, FR, US, US	0.5	0.25	0.25				1	
P=1: App: DE, US				0.5	0.5	0		1
P=2: Inv: DE, DE, FR, FR	0	0.5	0.5				1	
P=2: App: FR, US				0.5	0	0.5		1
P=3: Inv: FR, US	0.5	0	0.5				1	
P=3: App: US, US				1	0	0		1
$Inv_i = \sum_{p=1}^{P} Inv_{ip}$	**1**	**0.75**	**1.25**					
$App_i = \sum_{p=1}^{P} App_{ip}$				**2**	**0.5**	**0.5**		

Table 2. Computation of measures of internationalization of three fictitious patents

$InvInv_{ij} = \sum_{p=1}^{P} Inv_{ijp}$	j = US	j = DE	j = FR	$\sum_{j=1}^{N} InvInv_{ij} = Inv_i$
i = US	0.5	0.125	0.375	**1**
i = DE	0.125	0.3125	0.3125	**0.75**
i = FR	0.375	0.3125	0.5625	**1.25**
$\sum_{i=1}^{N} InvInv_{ij} = Inv_j$	**1**	**0.75**	**1.25**	

$AppApp_{ij} = \sum_{p=1}^{P} App_{ijp}$	j = US	j = DE	j = FR	$\sum_{j=1}^{N} AppApp_{ij} = App_i$
i = US	1.5	0.25	0.25	**2**
i = DE	0.25	0.25	0	**0.5**
i = FR	0.25	0	0.25	**0.5**
$\sum_{i=1}^{N} AppApp_{ij} = App_j$	**2**	**0.5**	**0.5**	

$InvApp_{ij} = \sum_{p=1}^{P} InvApp_{ijp}$	j = US	j = DE	j = FR	$\sum_{j=1}^{N} InvApp_{ij} = Inv_i$
i = US	0.75	0.25	0	**1**
i = DE	0.375	0.125	0.25	**0.75**
i = FR	0.875	0.125	0.25	**1.25**
$\sum_{i=1}^{N} InvApp_{ij} = App_j$	**2**	**0.5**	**0.5**	

Table 3. Type of applicant vs. type of internationalization.
Sample of 1000 international patents

	Type of internationalization			
			InvApp and:	
Type of applicant	Only InvApp	Only InvInv	Only AppApp	InvInv & AppApp
MNE HQ	71.0%	60.0%	48.8%	39.3%
MNE SUB	12.8%	12.6%	43.9%	10.7%
Firm	13.3%	18.3%	4.9%	17.9%
Universities	-	3.0%	2.4%	-
Public Res Inst	0.4%	3.5%	-	7.1%
Government	0.6%	0.3%	-	-
Person	1.7%	2.2%	-	25.0%
Sums by column	100%	100,00%	100%	100%
% in sample (n=1000)	53.1%	34.8%	6.5%	5.5%
% in pop. (N=224911)	55.6%	31.2%	6.9%	6.2%

Pearson χ^2 test on the independence of the two characters (18 degrees of freedom) = 145.9.
P-value = 0.000

Legend:
Type of applicant: A "Firm" is any firm, which is not a multinational corporation, or does not belong to one. MNC HQ: a Headquarter (HQ) of a multinational corporation (MNC), or a subsidiary, or a controlled firm, established in the same country as the headquarter. MNC SUB: a subsidiary of a MNE which is registered in a country different from HQ. Person: a physical person. Public Res Inst: Research institute that are financed mostly by public administrations. University: Universities and other types of higher education institutions.
Type of internationalization: see Section 2.

Table 4. OLS Regression results: The gravity model

VARIABLES	(1) ln(InvApp)	(2) ln(InvApp)	(3) Ln(InvInv)	(4) ln(InvInv)	(5) ln(AppApp)	(6) ln(AppApp)
ln(Inv$_i$)	0.550***	0.235				
	(0.171)	(0.147)	0.332**	0.0536		
ln(Inv$_j$)			(0.161)	(0.133)		
ln(App$_i$)						
					0.564**	-0.111
ln(App$_j$)	-0.250	0.145			(0.283)	(0.375)
	(0.346)	(0.173)				
ln(dist)	-0.247***	-0.518***	-0.241***	-0.321***	-0.129***	-0.589***
	(0.0288)	(0.0729)	(0.0232)	(0.0588)	(0.0367)	(0.0982)
Border	0.639***	0.393***	0.682***	0.678***	0.739***	0.339***
	(0.0575)	(0.0884)	(0.0466)	(0.0722)	(0.0717)	(0.121)
Com lang	0.297***	0.781***	0.682***	0.985***	0.120	1.895***
	(0.0892)	(0.191)	(0.0712)	(0.158)	(0.119)	(0.274)
EU Union	0.0500	0.612**	0.207***	0.561***	0.131	-0.284
	(0.0679)	(0.241)	(0.0539)	(0.194)	(0.0902)	(0.443)
Euro Zone	-0.102	0.325**	0.00556	0.143	-0.238**	0.834***
	(0.0902)	(0.155)	(0.0724)	(0.124)	(0.118)	(0.209)
Tech	0.719***	0.274	0.757***	0.443***	0.396***	-0.808***
	(0.0840)	(0.196)	(0.0637)	(0.156)	(0.121)	(0.305)
Lang sim	1.228***	0.328	0.931***	0.0902	0.741***	-0.936***
	(0.0972)	(0.228)	(0.0807)	(0.187)	(0.133)	(0.325)
Religion sim	0.421***	0.849***	-0.0971	0.235**	0.236	0.629***
	(0.108)	(0.133)	(0.0860)	(0.106)	(0.163)	(0.234)
Trust		0.487**		0.866***		1.056***
		(0.240)		(0.195)		(0.360)
Somatic dist		-0.0720***		-0.0200		-0.0461
		(0.0273)		(0.0224)		(0.0418)
IPR$_i$	-1.318	-0.731				
	(0.976)	(0.942)	-0.465	0.856	-2.725**	-1.141
IPR$_j$	0.301	1.077	(0.600)	(0.591)	(1.130)	(1.683)
	(1.263)	(0.716)				
ln(FDI flow out)$_i$	0.247*	0.312				
	(0.147)	(0.241)	0.109	0.315	0.279	-0.563
ln(FDI flow out)$_j$	-0.260**	-0.688**	(0.115)	(0.235)	(0.221)	(0.543)
	(0.133)	(0.325)				
ln(FDI flow in)$_i$	0.315	0.387*				
	(0.236)	(0.197)	0.130	-0.0799	0.203	0.621
ln(FDI flow in)$_j$	0.315	0.485**	(0.146)	(0.135)	(0.329)	(0.396)
	(0.236)	(0.194)				
ln(FDI stock out)$_i$	0.375	-0.0356				
	(0.288)	(0.394)	0.0208	-0.373	0.198	-0.303
ln(FDI stock out)$_j$	0.388	0.539	(0.184)	(0.285)	(0.540)	(0.734)
	(0.246)	(0.332)				
ln(FDI stock in)$_i$	-0.0953	-0.151				
	(0.138)	(0.362)	0.0527	0.518*	-0.259	2.254***
ln(FDI stock in)$_j$	-0.435**	0.234	(0.109)	(0.286)	(0.298)	(0.722)
	(0.179)	(0.413)				
Observations	6314	1854	6916	1890	3986	1244
R-squared	0.749	0.791	0.768	0.832	0.644	0.745

Notes:

Columns: 1, 3 & 5: All (42) countries; 2, 4 & 6: Subset of EU countries, plus Norway (14 countries).

Robust standard errors in parentheses, *** p<0.01, ** p<0.05, * p<0.1

Time-varying fixed country effects included in the regression. Years considered: 1990-2005

Table 5. Regression results: Changes in time of the distance elasticity. Weighted OLS

	OLS			POISSON		
Type of internationalization	InvApp	InvInv	AppApp	InvApp	InvInv	AppApp
42 countries						
p-value	0.000	0.000	0.005	0.451	0.000	0.000
Significant estimates	11	13	7	14	16	10
R^2	0.476	0.611	0.306	0.014	0.510	0.783
Implied elasticity, 1990	-0.157	-0.071	-0.364	-0.284	-0.196	-0.880
Implied elasticity, 2005	-0.329	-0.437	0.324	-0.261	-0.370	+0.052
14 countries						
p-value	0.000	0.000	0.009	0.003	0.378	0.000
Significant estimates	14	9	5	14	11	12
R^2	0.504	0.491	0.309	0.165	0.018	0.728
Implied elasticity, 1990	-0.879	0.154	-1.392	-0.721	-0.360	-1.339
Implied elasticity, 2005	-0.481	-0.709	-0.365	-0.494	-0.416	-0.213

Notes:

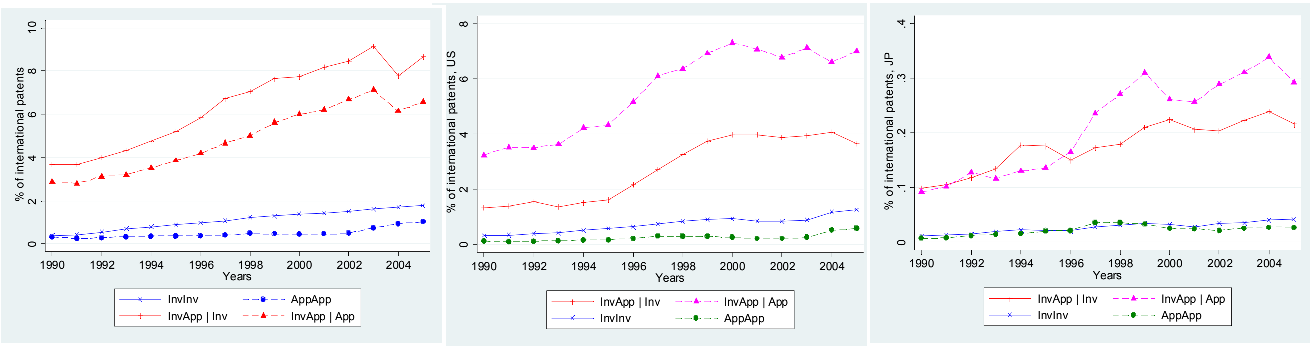
n=16. p-value of the estimated slope of a regression having the estimates of the distance elasticities (by year), as the dependent variable, and time as the explanatory variable.

The weights are equal to the estimated coefficient of *ln(dist_km)*, divided by its estimated standard error. Implied elasticities are computed as the forecasts of the distance elasticities for the first and the last years of the period under consideration.

Figures

Figure 1. International patent, EU27, national averages

EU27 national average United States Japan



Notes:
InvInv | Inv: Eq. 8; AppApp | App: Eq. 8'; InvApp | Inv: Eq. 9; AppInv | App: Eq. 9'
Source of the data: Analysis of the Patstat database (April 2009 release) (See Section 3 for a description).

APPENDIX

A. The countries considered for the analysis.

Measures of the internationalization of inventive activities have been computed for a total of 42 countries. These are:

All OECD countries: Australia, Austria, Belgium, Canada, Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Japan, Korea, Luxembourg, Mexico, Netherlands, New Zealand, Norway, Poland, Portugal, Slovak Republic, Spain, Sweden, Switzerland, Turkey, United Kingdom, United States);

Countries "invited […] to open discussions for membership to the [OECD]: Brazil, China, India, Indonesia and South Africa;

Countries included into the "roadmaps" [marking] the start of accession talk [to the OECD]: Chile, Israel and Russia and (from the site of the OECD, accessed on 15 October 2009); Estonia and Slovenia also belong this group, but they have not be considered for problems of data coverage.

Countries that, while not belonging to the groups above, are part of the European Union (with the exclusion of Cyprus and of Malta, whose patenting activities are either zero or negligible): Lithuania, Bulgaria and Romania; Latvia also belong to this group, but it has not be considered for problems of data coverage.

Taiwan.

The gravity model is also estimated on a group of 14 countries, for which the *Trust* and *Somatic dist* variables also available. These are: Austria, Belgium, Denmark, Finland, France, Greece, Ireland, Italy, Netherlands, Norway, Portugal, Spain, Sweden, United Kingdom.

B. Definition of variables and data sources.

Tech. The technological proximity variable is computed considering the eight top "sections" (A through H) of the International Patent Classification (IPC) taxonomy. See http://www.wipo.int/classifications/ipc/en/ (last accessed on 15 October 2009). The correlations are computed for each year on the same dataset used for all the exercises carried out in the paper. Fractional counting is adopted to address all the cases when more than one IPC category is assigned to a patent.

Com lang. It is equal to 1 if two countries the same language is spoken, 0 otherwise, and it takes fractional values for multilingual countries. For example, it is equal to one half between Belgium and France (the presence of a small German speaking minority in Belgium is ignored), and to one third for the pairs of Switzerland with Germany, France and Italy.

Trust. From Guiso et al. (2009), based on the Eurobarometer survey.

Som dist. It is based on the distance between a set of four anthropometric measures. The source is Guiso et al (2009).

Lang sim. The similarity between couple of languages is computed using data from the Ethnologe Project (http://www.ethnologue.com/), as collected and organized by James Fearon (see Fearon, 2003). The similarity between two languages is based on the distance between "tree branches" ("for example [...] Byelorussian, Russian and Ucrainian share their first three classifications as Indo-European, Slavic, East Branch languages"; Fearon, 2003). Unlike in Fearon's work, who obtains his measure by dividing the number of branches that are in common by the maximum number of branches that any language has (which is equal to 15), we divide by the maximum number of branches of each couple of language, so as to take into account that the granularity of the branch definition may be not the same across languages.

Religion dist. It is the probability that two persons in different countries belong to the same broad group of religions. The computation is based on data from the World Value Survey (http://www.worldvaluessurvey.org/), integrated with data from the CIA World Factbook for the countries not covered therein.

IPR. The source of the data, available for 1995, 2000, 2005 and an average of 1960-1990, is Park (2008). For the years 1990, 1991 and 1992, the 1960-1990 average has been used. The years 1993, 1994, 1996 and 1997 are set equal to the observation for 1995. The observation for year 2000 is also used for the years 1998, 1999, 2001 and 2002. Last, the observation for year 2005 is also used for the years 2003 and 2004.

Table A.1. Poisson estimates

VARIABLES	(1) *InvApp*	(2) *InvApp*	(3) *InvInv*	(4) *InvInv*	(5) *AppApp*	(6) *AppApp*
ln(Inv$_i$)	0.418***	0.337***				
	(0.0630)	(0.111)	0.431***	0.115		
ln(Inv$_j$)			(0.0590)	(0.105)		
ln(App$_i$)						
					0.551***	0.254
ln(App$_j$)	0.541***	0.383***			(0.128)	(0.220)
	(0.0884)	(0.134)				
ln(dist)	-0.252***	-0.470***	-0.332***	-0.394***	-0.342***	-0.670***
	(0.0298)	(0.0526)	(0.0198)	(0.0397)	(0.0422)	(0.0853)
Border	0.356***	0.190***	0.519***	0.498***	0.850***	0.202
	(0.0566)	(0.0691)	(0.0381)	(0.0535)	(0.0916)	(0.135)
Com lang	0.252**	1.082***	0.398***	1.361***	-0.197	2.960***
	(0.102)	(0.136)	(0.0633)	(0.133)	(0.162)	(0.275)
EU Union	0.210***	0.304***	0.198***	-0.169**	0.194	0.155
	(0.0600)	(0.0853)	(0.0448)	(0.0726)	(0.118)	(0.243)
Euro Zone	0.0438	0.242***	0.0246	-0.00351	-0.240*	0.430***
	(0.0681)	(0.0711)	(0.0352)	(0.0440)	(0.134)	(0.119)
Tech	1.004***	0.497***	1.033***	-0.165	1.199***	-1.397***
	(0.0936)	(0.171)	(0.0543)	(0.152)	(0.163)	(0.385)
Lang sim	0.586***	0.243	0.554***	0.231**	0.358	-1.334***
	(0.130)	(0.162)	(0.100)	(0.105)	(0.230)	(0.252)
Religion sim	-0.0890	0.537***	-0.743***	-0.669***	0.492**	0.971***
	(0.160)	(0.196)	(0.0971)	(0.133)	(0.239)	(0.303)
Trust		1.823***		0.843***		-0.0891
		(0.193)		(0.151)		(0.365)
Somatic dist		-0.0582**		-0.0697***		-0.458***
		(0.0252)		(0.0263)		(0.0502)
IPR$_i$	0.0918	0.367*				
	(0.0671)	(0.190)	0.120**	0.328**	0.159	1.314***
IPR$_j$	0.0846	0.584***	(0.0538)	(0.162)	(0.117)	(0.334)
	(0.0370)	(0.0436)				
ln(FDI flow out)$_I$	0.00567	-0.0435				
	(0.0221)	(0.0335)	-0.0315**	-0.00445	-0.0785**	-0.132
ln(FDI flow out)$_j$	-0.0137	-0.0301	(0.0150)	(0.0224)	(0.0399)	(0.0911)
	(0.0284)	(0.0322)				
ln(FDI flow in)$_i$	0.0109	-0.00270				
	(0.0230)	(0.0262)	0.0268*	0.00718	0.0586	0.0833
ln(FDI flow in)$_j$	0.00905	-0.0665**	(0.0162)	(0.0184)	(0.0372)	(0.0520)
	(0.0224)	(0.0318)				
ln(FDI stock out)$_i$	0.204***	0.225**				
	(0.0636)	(0.112)	0.164***	0.247***	0.342***	0.0893
ln(FDI stock out)$_j$	0.0329	0.148	(0.0470)	(0.0881)	(0.100)	(0.254)
	(0.0862)	(0.140)				
ln(FDI stock in)$_i$	-0.152***	-0.132				
	(0.0520)	(0.115)	-0.148***	-0.253***	-0.211**	0.0326
ln(FDI stock in)$_j$	0.133*	0.304***	(0.0357)	(0.0972)	(0.0848)	(0.255)
	(0.0807)	(0.118)				
Observations	16730	2620	16730	2620	16730	2620
R-squared	0.906	0.900	0.665	0.651	0.579	0.354

Notes:

Columns: 1, 3 & 5: All (42) countries; 2, 4 & 6: Subset of EU countries, plus Norway (14 countries).

Robust standard errors in parentheses, *** p<0.01, ** p<0.05, * p<0.1

Time-varying fixed country effects included in the regression. Years considered: 1990-2005