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Knowledge Flows And Public-Private Cooperation Across National Contexts

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Abstract: This paper investigates the influence of country-specific factors on the degree of reliance on public knowledge among innovators. Using backward citations as our dependent variable we find that national characteristics indicative of the quality of the innovation system generally have a positive effect on knowledge flows. A national bias towards applied research and development (R&D) has a negative impact, but this is moderated by individual public-private cooperation. Overall, our empirical exercise confirms the strong mutual influence of the characteristics of applicants and the attendant institutional context, thus contributing to the debate on the centrality of university/government-industry interaction in the current policy debate. Our sample consists of some 600,000 patents from the EU27 member states in years 1990-2007. The policy implications of our empirical exercise suggest the importance of strengthening the quality of innovation infrastructures and of setting targets for the composition of R&D funding to achieve a balance between patent knowledge production and knowledge flows. Last but not least, this analysis provides broad support for policies aimed at enhancing public-private cooperation to compensate for the effects of strong bias in the direction of national research.

Keywords: knowledge flows, innovation systems, national innovative capacity, patents, citations
JEL Codes: O31, O32, O33

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1 Introduction

A knowledge flow is a communication act that implies the transmission of information from sender to receiver. The existence of channels facilitating such flows within organizations and countries has been highlighted as a crucial precondition for successful knowledge creation (Nonaka, 1994). Patents are codified sources of scientific and technological information about new knowledge (invention) and knowledge flows (the state-of-the-art). Examiners and applicant(s) include citations to previous patents and other documents that question or vindicate the novelty of the invention, thus conveying a description of part of the knowledge flows related to the patent (Narin et al., 1997). Backward references in patents are a measure of knowledge flows, which, despite their well-known limitations (see e.g. Jaffe et al., 1993), remain valuable predictors of forward references and, thus, of the value of the patent (Harhoff et al., 2003). The purpose of the paper is to analyse what determines numbers of backward references in patents.

Work on the sources, effects and meaning of knowledge flows across organizations and also geographical boundaries (see e.g. Hall et al., 2005) tend to focus on issues such as forward citations as indicators of patent value (Kamiyama et al., 2006), and systematic measurement errors which ultimately undermine the usefulness of patent citations for studying knowledge flows. Less attention has been paid to what influences backward references, and their links with the broader institutional environment. Characteristics of patents, such as type of technology and cited literature, are identified, but tend to be discussed in a rather descriptive fashion (Tijssen, 2001; Callaert et al., 2006). These works show that the number of backward references in patents varies across technologies, years, patent offices, etc. In this paper we focus on country-specific characteristics as a peculiar yet understudied feature of patents, in light of the widely accepted notion that resource endowment and technological specialization shape patterns of knowledge generation and diffusion (Antonelli, 2008). We also try to uncover the connection between country-specific characteristics and knowledge flows.

The focus on country-specific characteristics and knowledge flows has conceptual and practical relevance. Country-specific characteristics are at the heart of an ongoing debate concerning the reliability of national comparisons of innovation system performance. Policy-oriented studies seeking to establish rules of thumb for enhancing innovation opportunities have spurred a proliferation in benchmarking studies that analyse innovation indicators to identify best practice and to derive policy recommendations (see e.g. OECD, 1998). However, as Balzat and Hanusch (2004) point out, although this stream of research enriches the set of empirical indicators and methods, it obscures systemic dissimilarities across different national contexts. The present paper addresses this shortcoming and uses a standardized set of country-specific characteristics to highlight differences across national contexts. More specifically, we explore the influence of the background conditions for knowledge production such as quality of the innovation infrastructure, composition of R&D funding and expenditure, and public-private cooperation.

The remainder of the paper is structured as follows. Section 2 introduces the main conceptual issues; Section 3 presents the data and the methodology, and Section 4 provides a discussion of the results and their implications. Section 5 concludes and summarizes our findings.

2 Literature review

This section explores and builds on three literature strands to elaborate our hypotheses.

2.1 The national institutional context

The influence of the institutional environment on innovation performance has for long been acknowledged in the innovation literature. This issue is often addressed in the context of national innovation system (NIS) theory, which emerged in the late 1980s to conceptualize the complex components and relations underpinning the dynamics of economic growth (see Freeman, 1987; Lundvall, 1992; Nelson, 1993; Edquist, 1997). Central to NIS theory is the idea that technology, as a key driver of innovation, is a strongly contextual process influenced by organizational and institutional forces, typically concentrated in firms. At the heart of the systemic perspective, are rebuttal of linear approaches to innovation and full appreciation of the complex nexus of interactions that characterize the modus operandi of economies. Since its introduction, the NIS approach has elaborated conceptual frameworks comprised of the main actors involved in innovation and the structure of their relations, within a variety of empirical contexts, mostly industrialized countries, but, more recently, also a selection of emerging countries. Over time, research on NIS has developed along several related strands: depending on the level of analysis, innovation systems are conceptualized along regional, sectoral or technological dimensions, the common element in these perspectives being the distributed problem-solving nature of innovation (see Consoli and Mina, 2009 for a review).

Elaborations of this conceptualization include evaluation and comparison of national innovation performance using numerical scores and cross-national rankings (see e.g. Porter and Stern, 2001; Balzat and Pyka, 2006; Castellacci, 2008). Furman et al. (2002: 900) propose the concept of ‘national innovative capacity’ (NIC), ‘the ability of a country to produce and commercialize a flow of innovative technology over the long term’ as a framework to analyse the interplay among infrastructure, cluster conditions and linkages to measure. The NIC concept draws on endogenous growth theory (see e.g. Romer, 1990), international competitiveness (Porter, 1990) and the traditional NIS approach. Alternatives have been proposed by Nasierowski and Arcelus (2000), who group countries according to their level of technological capabilities, and Castellacci and Archibugi (2008), who look at a broad set of technological and infrastructure indicators and identify three groups, namely 'technological leaders', 'followers' and 'marginalized' countries.

A robust observation emerging from all the aforementioned studies is that the growing gap between leaders and laggards is due to structural, such as natural resource endowments, as well as dynamic factors, that is, the particular combination of technological complex, institutional infrastructures and conditions for learning in place in a country. In other words, the quality of the innovation infrastructure is a powerful determinant of a country's capacity to innovate and, by extension, to facilitate knowledge flows.

2.2 The structure of funding and performance of research and development

In this section, we examine two measures of the R&D structure: share of business R&D funding, and share of university R&D expenditure. According to Sapir (2003) a large share of business funding of R&D is a good indicator of differences between more or less innovative country blocks such as US versus EU, or between countries within Europe – for example in Finland, Sweden and Germany compared to the Mediterranean countries. The widespread decrease in business R&D funding observed across OECD countries in 1981–2003 (Dinges et al., 2007) has become the target for policy. For example, the Lisbon Strategy in 2000 set a target of two-thirds of total R&D funding should be business funding compared to the (then) 55% share (target set at Barcelona in 2002, EC 2002: 24).[2]

Furman et al. (2002: 913-14) put business R&D funding at the core of their NIC concept:

> *We employ the intensity of privately financed R&D activity in an economy to measure the collective importance of innovation-based competition across clusters. Conditional on the overall level of R&D investment in an economy, the fraction of total R&D spending conducted by the private sector provides a useful summary indicator of the vitality of the environment for innovation in national industrial clusters that is comparable across countries and available for an international sample. This measure does not, of course, explicitly portray the subtle implications of industrial clusters, but does reflect a broader theme arising from that perspective: the productivity of innovative investment will depend on whether private firms within the economy are choosing to direct resources towards that end.*

Furman and co-authors find a positive effect of business R&D funding on NIC (measured as number of patents) in various developed OECD economies (Furman et al., 2002). The same effect is observed among the catching up countries (Furman and Hayes 2004), most prominently latecomer East Asian economies (Hu and Matthews, 2005) and China (Hu and Matthews, 2008). Some suggest that the positive effect holds only for small open economies and that in other economies the effect is negative (Doyle and Connor, 2013).

[2] Curiously, if we also include non-university public research organizations, the share of business funding of R&D in the higher education and government sectors is increasing in Europe, and is higher than in US (De Backer et al., 2008).

Despite this established view that a large share of business R&D funding at country level has a positive impact on knowledge production, we expect the impact on knowledge flows will be negative. This is because business firms tend to fund corporate R&D that is privately profitable, whereas governments tend to fund corporate R&D in the expectation that it will generate social benefits that firms are unlikely to pursue on their own initiative (Nelson, 1959; Arrow, 1962; Wallsten, 2000). With a few exceptions, business funding usually supports inventive efforts and less risky, shorter-term research with tangible results, that is, applied R&D rather than basic research. Applied R&D is more likely to generate incremental rather than radical innovations and, as Azagra-Caro et al. (2009) show, knowledge flows are scarce in geographic contexts where incremental invention prevails. Moreover, sectors specialized in incremental innovation benefit especially from changes in demand and interactions with customers and suppliers, compared to sectors oriented more towards radical innovation and, consequently in search of scientific and technological knowledge flows, for example, science-based sectors (Schartinger et al., 2002). The preference among business R&D funders for activities that involve less intensive knowledge flows raises concern when firms outsource these activities to universities or public research organizations (Goldfarb, 2008).

However, business R&D funding is only one facet of the institutional structure of national R&D. The share of university expenditure on R&D is another important determinant of innovation according to the NIC approach. Furman et al. (2002: 918) advocate that:

> *University research tends to be more accessible to researchers in industry than government laboratory research, and universities provide a forum for the exchange of ideas between different R&D communities. The unique role that universities play in training future industrial researchers suggests another way in*

which common resources for innovation (i.e. S&E graduate students) are mobilized in a nation's industrial clusters.

They find a positive effect of share of university R&D in innovation. However, this evidence is less robust in relation to the funding structure, in that the effect is insignificant for follower countries (Furman and Hayes, 2004), and latecomer East Asian countries (Hu and Matthews, 2005) except China (Hu and Matthews, 2008). The effect is positive, but minor for Spain (Buesa et al., 2002) and for small open economies, while it is negative for the remaining countries (Doyle and Connor, 2013). A caveat in the article by Furman et al. may explain the scant evidence available. Their argument about the importance of universities suggests a positive effect of the intensity of university R&D expenditure on innovation, for example, university R&D over GDP. However their construct – share of university expenditure over total GERD – has little to do with the intensity of academic R&D because countries with a high share of university R&D expenditure may simply have very few firms able to conduct R&D, which is not necessarily to imply that their universities are scientifically strong. In fact, it is difficult to predict the effect of the institutional structure of R&D expenditure on patenting. By contrast, empirical evidence that a large proportion of R&D performed by universities in a country produces a direct positive effect on patenting suggests that the former is an indicator of the industrial orientation of universities' R&D.

To illustrate, Table 1 shows that the share of university R&D expenditure in total government expenditure on R&D (GERD) is not correlated with university R&D intensity, but instead is correlated with share of business funding of university R&D (positive sign) and share of university R&D corresponding to basic research (negative sign). In Eurostat countries (mostly European) where universities account for the largest share of basic research, business firms fund relatively more R&D, mostly applied in nature. Although using share of university expenditure on R&D over total GERD in the NIC perspective outlined above may be somewhat misleading, it remains a useful indicator since the number of observations is larger compared to business funding of academic R&D and share of basic university research.

{Table 1 around here}

As in the case of a large share of business funding, we posit that industrial orientation of national R&D carried out in universities will lead to fewer knowledge flows because of the narrower scope of the universities' industrial compared to their academic activities.

2.3 The moderating role of cooperation

Cross-institutional collaboration is a central ingredient of knowledge creation and knowledge flows (Nonaka, 1994). This theme has been debated in various strands of the scholarly literature. The rationale underpinning scientific cooperation is ascribed to benefits such as resource pooling, economies of scope, and enhanced access to specialized expertise and instrumentation (Hagedoorn et al., 2000; Katz and Martin, 1997). The innovation literature understands research cooperation as a vehicle to reduce uncertainty, both ex-ante uncertainty related to the search for new solutions and the exploration of alternative options, and ex-post uncertainty due to market competition (Nelson, 1990; Metcalfe, 2002). The first conceptual contribution in this direction is Kline and Rosenberg's (1986) argument that accumulated knowledge is essential not just in the exploratory stages, but throughout the entire innovation process, via incremental feedback generated via collaboration across specialized actors. Further efforts in this direction gave shape to a more systematic understanding of the wide range of possibilities for cooperative arrangements in the context of innovation systems, and a detailed appreciation of the channels through which they can be implemented (Lundvall, 1992; Nelson, 1993). University-industry-government cooperation within innovation systems can boost opportunities to align academic excellence with commercial potential (Ranga and Etzkowitz, 2013).

Empirical studies show that the interplay between firms and their operating environment is essential for knowledge creation. A chief cause of growing reliance on external knowledge is the necessity to coordinate different forms of knowledge embedded in increasingly complex production processes (Howells, 2000). Cross-country studies on innovative activities in the manufacturing industries show that information networks are crucial for innovative outcomes (see e.g. De Bresson and Amesse, 1991). In a nutshell, isolated firms achieving innovation through their own resources are ‘rare events’. At the same time, collaboration with public research institutions is not always a recipe for success. As Hall (2002) shows, universities tend, perhaps naturally, to be involved in radically new applications of previously known technology. The broader point is that public-private cooperation occurs more frequently in endeavours where the expertise of research institutions is needed to reduce the margins of uncertainty. This echoes the old adage that public R&D is a framework condition for innovative performance (Mansfield, 1998). From the point of view of academics, engagement in contract research coincides with increased publication output without affecting the nature of the publications involved (Van Looy et al., 2004).

3 Methodology and data

Based on the arguments discussed in sections 2.1, 2.2 and 2.3 respectively, the following hypotheses are defined:

Hypothesis 1. The quality of the innovation infrastructure positively influences knowledge flows.

Hypothesis 2. Patents originating from NIS with higher shares of business funding of R&D relative to other sources, and higher shares of public expenditure of R&D relative to other performers, will capture fewer knowledge flows.

Hypothesis 3. Public-private cooperation positively moderates the relationship between the share of business R&D funding, the share of university R&D expenditure and knowledge flows.

The remainder of the paper proposes an empirical exercise based on a large sample of patents in the period 1990-2007 to test these hypotheses.

Our measure of knowledge flows is number of backward references in patent data collected by the Institute for Prospective Technological Studies (IPTS) in 2009. Backward references are citations to previous patents or other published documents, mainly scientific articles. Figure 1 synthesizes the sample construction.

{Figure 1 around here}

Using European Patent Office (EPO) Worldwide Patent Statistical Database (PATSTAT) we constructed a dataset of nearly 650,000 patents applied for by inventors located in any of the EU27 Member States in the period 1997-2007. The original dataset containing the number of backward references of direct EPO patents was integrated with additional information on the number of backward references of EPO-PCT using OECD patent databases.

In the final sample of over 700,000 patents the average number of applicants from different countries per patent is 1.1. Patents with missing information (mainly related to technology class) and outliers (patents with at least 20 backward references, according to the Hadi method) are excluded. Finally, we matched country of the citing applicant (in a given year) to Eurostat national economic and R&D statistics (with a lag of two years).

The final sample includes more than 560,000 observations. The average number of backward references per patent is about 5 and has been relatively stable over the period.

Figure 2 suggests that there is country variation in the number of references per patent. Patents with US co-applicants include more references (6.01), perhaps due to the cultural differences created by the USPTO duty of candour, although the EPO system is less strict about references. Among EU27 countries, the highest number of references (5.44) are in patents from Belgium while the lowest numbers (4.66) are in patents from Sweden.

{Figure 2 around here}

We explain country heterogeneity and other variations in the number of backward references using the following model:

$$\begin{aligned}
&nbackref_{ijkt} = f(epopct_{it}, appy_{it}, IPC_{it}, institutional\ \sec tor_{jt},\\
&public\text{-}private\ cooperation_{jt}, non\text{-}EU27\ co-applicants_{jt},\\
&per\ capita\ GDP_{k,t\text{-}2}, sHTE_{k,t\text{-}2}, GERD_{k,t\text{-}2}, sBFRD_{k,t\text{-}2}, sHERD_{k,t\text{-}2},\\
&sBFRD_{k,t\text{-}2} \times public\text{-}private\ cooperation_{jt},\\
&sHERD_{k,t\text{-}2} \times public\text{-}private\ cooperation_{jt})
\end{aligned}$$

i=patent, j=applicant, k=country of applicant, t=year of application

Table 2 presents the list of variables and their description. Per capita GDP, sHTE and GERD allow us to test Hypothesis 1, sBFRD and sHERD refer to Hypothesis 2 and sBFRD x public-private cooperation and sHERD x public-private cooperation to Hypothesis 3. The remainder are control variables for patent and applicant characteristics.

Since number of backward references is a count outcome, we employ Poisson, negative binomial, zero-inflated regression techniques.

{Table 2 around here}

4 Results

Table 3 presents some descriptive statistics for the whole sample. 55% of the patents are EPO direct applications, 45% are EPO-PCT applications. The most represented technology is in the class 'Performing Operations; Transporting'. Business firms comprise 88% of patent applicants in collaboration with university or government bodies in only 0.4% of cases. The sample includes 1% of non-EU27 co-applicants. The countries considered have real per capita GDP over 25,000 euros, a share of 19% of high-tech exports over total exports, a GERD of almost 30,000 million Purchasing Power Standards (PPS), 57% of BFRD over GERD and 19% of HERD over GERD.

{Table 3 around here}

Table 4 shows that EPO-PCT patents have more references than direct EPO patents. Patents that are more recent have larger numbers of references. There is variation according to the technology class of the patent: belonging to classes A, B, C, F and G increases the number of references, being in E has no effect, and being in D and H decreases the number. For institutional sectors, companies are the benchmark. Patents applied for by applicants from other institutional sectors have more references, as shown by the positive and significant coefficients. Our variable for public-private cooperation is also positive and significant, so if companies co-apply for patents with universities and/or government bodies, the number of references increases. Having non-EU27 co-applicants does not have a significant effect.

{Table 4 around here}

Regarding applicant country characteristics, more references correspond with higher levels of per capita GDP, larger shares of high-tech exports and higher GERD. This supports Hypothesis 1. Looking at the marginal effects, the number of backward references increases by 1.00-5 with a 1% increase in per capita GDP, by 0.7 with a 1% increase in share of high-tech exports, and by 2.52-6 with a 1% increase in GERD.

The average patent has fewer references if the applicant is from a country with higher shares of business funding and university expenditure over total R&D. This supports Hypothesis 2. Marginal effects indicate that a 1% increase in share of BFRD (HERD) causes a 1.0 (0.3) decline in the number of backward references.

The interaction terms between sBFRD, sHERD and the variable 'public-private cooperation' are positive and significant. This confirms Hypothesis 3 and suggests that individual interactions moderate the negative effect of national context.

As a robustness check, we split backward references according to cites to patent and non-patent literature (PL and NPL). We argue that the former represent a more applied knowledge base than the former. Since we justified that the negative effect of share of business funding and university expenditure on the knowledge base on the basis that they indicate an applied orientation of the economy, we expect that Hypothesis 2 and Hypothesis 3 will hold especially for NPL –NPL in view of the fundamental nature of the knowledge base.

The results in Table 5, Column 1, show that for PL, Hypothesis 1 holds, but Hypothesis 2 holds only for share of business funding, not share of university expenditure, and we find no support for Hypothesis 3. In Column 2, we see that, in general, all the hypotheses hold. Notice, however, that the negative impact of share of business funding is higher for PL than NPL (marginal effect of 0.5 versus 0.3) suggesting that the institutional composition of R&D plays an important role. In addition, public-private cooperation does not moderate this phenomenon for PL.

A surprising result against Hypothesis 1 for NPL is the negative sign of GERD which is very robust to alternative specifications (e.g. removing the top patenting country Germany; trying different time periods; transforming the variables in logs or using R&D intensity instead), and which we will try to elucidate in future research.

{Table 5 around here}

5 Concluding remarks and further research

This paper analysed the determinants of knowledge flows across different national innovation systems. We extracted backward citations from a large dataset of patents and used them as the dependent variable among a broad set of indicators to account for both applicants' and countries' characteristics. This empirical exercise suggests that the overall quality of a national innovation system is a positive predictor of knowledge flows. The policy implication is that promoting both knowledge creation in the terms of other studies as well as knowledge flows in the terms of the present study.

At the same time we find that the composition of R&D by institutional sector (funding and expenditure) matters for knowledge flows. This calls for policies that set targets for share of business R&D funding and share of university R&D expenditure. Indeed we find that a stronger bias towards private enterprise in the composition of total R&D has a negative impact on the extent to which inventors and examiners acknowledge the state-of-the-art. This is ascribed to the predominance of an incentive system that particularly privileges applied inventions and, therefore, relies on a narrower (as opposed to basic scientific) knowledge base. Since the effect of the composition of R&D by institutional sector on national patenting found in other works (see section 2.2) goes in the opposite direction, our findings suggest the existence of a trade-off between knowledge creation and knowledge flows. The intuition is that the applied orientation of research in a country will lead to higher levels of patenting but, also, to fewer knowledge flows. Policymakers seeking to maximize both will need to take this into account when setting targets for the composition of R&D.

Conversely, public-private cooperation is observed to mitigate the aforementioned bias, and the negative impact of business oriented R&D holds up to a threshold, above which the effect becomes positive. The policy implication is that institutional characteristics (public-private cooperation) moderate the bias of the national context. This applies more to basic than applied knowledge, that is, individual public-private cooperation changes the negative influence of an adverse applied context such that it increases the basicness of the knowledge base.

These results complement the literature on knowledge flows which so far has tended towards only one direction, namely analysis of forward citations. Considering the broader institutional environment as the explanatory dimension seems a reasonable starting point to unpack the effect of country characteristics on knowledge flows. Our study adds to the ongoing debate on the impact of resource endowments and direction of inventive efforts across National Innovation Systems, and confirms that the interplay between firms and their institutional counterparts is an important propeller of knowledge flows. This latter finding resonates with the broader tendency to rely on a broader knowledge base as way to coordinate different capacities in the context of increasingly complex production systems.

Perhaps unsurprisingly, a preliminary study such as ours has several limitations. First, the aggregate level at which this analysis is carried out cannot capture inter-industry differences in patenting, and the spillovers from these in the form of inputs to future R&D. Furthermore, the ambiguous sign of the R&D coefficient in the determination of NPL may be due to some endogenous effect of allocation decisions on the part of either public research organizations or business firms as a response to opportunities allowed by specific technological advances. At present these questions remain open and can only be unpacked by means of micro-level studies that control for the effects of cross-industry and temporal changes in the distribution of technological opportunities. Finally, the extent to which private R&D is affected by particular appropriability conditions or by publicly generated benefits in areas of new technological opportunities may depend on the particular circumstances of individual countries. Greater availability of international data would allow deeper investigation of these issues in the future.

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Tables and Figures

Tab. 1 Higher education expenditure on R&D in Eurostat countries, 1988-2005

	Observations	Mean	Correlation with share of gross expenditure on R&D
Share of gross expenditure on R&D	414	.25	1.00
Percentage of gross domestic product	453	.32	0.11
Share of business funding	389	.07	0.21*
Share of basic research	197	.54	-0.43*

* Significant at 1%. Source: own elaboration from Eurostat data.

Tab. 2 List of variables

Variable	Description
Patent characteristics	
nbackref	Number of backward references
appshare	1/Number of applicants (used as weight)
epopct	Dummy=1 if EPO-PCT patent, 0 if direct EPO patent
appy *	Application year
IPC: A, B, C, D, E, F, G, H	Dummy=1 if patent classified in a given IPC
Applicant characteristics	
Institutional sector: company, individual, non-profit, university, government, hospital	Dummy=1 if applicant classified in a given institutional sector
Public-private cooperation	Dummy=1 if at least one applicant is a company and at least one applicant is either a university or a government body
Non-EU27 co-applicants	Dummy=1 if the applicant's country does not belong to the EU27
Applicant country characteristics	
Per capita GDP	Real Gross Domestic Product (GDP): Euro per inhabitant
sHTE	High-technology exports: Share of manufactured exports
GERD	Total intramural Gross R&D expenditure (GERD): Millions of Purchasing Power Standards (PPS) at 2000 prices
sBFRD	Business R&D funding: Share of GERD
sHERD	Higher education R&D expenditure: Share of GERD

We have tried time dummies instead of time trend, with identical results but higher collinearity.

Tab. 3 Descriptive statistics (n= 563,360)

Variable	Mean	Std. Dev.	Min	Max
nref	4.936	2.717	0	19
epopct	0.447	0.497	0	1
appy	1,999.434	4.326	1,990	2,007
A Human Necessities	0.198	0.399	0	1
B Performing Operations; Transporting	0.279	0.449	0	1
C Chemistry; Metallurgy	0.197	0.398	0	1
D Textiles; Paper	0.030	0.171	0	1
E Fixed Constructions	0.058	0.234	0	1
F Mechanical Engineering; Lighting; Heating; Weapons; Blasting	0.141	0.348	0	1
G Physics	0.195	0.396	0	1
H Electricity	0.206	0.404	0	1
Company	0.877	0.328	0	1
Individual	0.083	0.276	0	1
Nonprofit	0.016	0.124	0	1
University	0.011	0.104	0	1
Government	0.013	0.113	0	1
Hospital	0.000	0.016	0	1
Public-private cooperation	0.004	0.063	0	1
Non-EU27 co-applicants	0.007	0.086	0	1
Per capita GDP *	25,093.140	3,004.351	1,900	65,000
sHTE *	0.187	0.061	0.012	0.590
GERD *	29,888.120	19,136.160	16.648	249,298.400
sBFRD *	0.567	0.085	0.137	0.907
sHERD *	0.192	0.044	0.002	0.671

Weight variable: share of number of applicants * Centered for the estimations

Tab. 4 Zero inflated negative binomial estimation of the determinants of number of backward references: PL vs. NPL

	1 Patent literature	2 Selected marginal effects	3 Non-patent literature	4 Selected marginal effects
epopct	0.03***		0.97***	
	(0.00)		(0.01)	
appy	0.19***		0.15	
	(0.02)		(0.10)	
A Human Necessities	0.07***		0.28***	
	(0.00)		(0.01)	
B Performing Operations;	0.11***		-0.98***	
Transporting	(0.00)		(0.01)	
C Chemistry; Metallurgy	-0.06***		0.88***	
	(0.00)		(0.01)	
D Textiles; Paper	0.06***		-0.82***	
	(0.00)		(0.03)	
E Fixed Constructions	0.07***		-1.60***	
	(0.00)		(0.04)	
F Mechanical Engineering; Lighting;	0.13***		-1.29***	
Heating; Weapons; Blasting	(0.00)		(0.02)	
G Physics	-0.04***		0.50***	
	(0.00)		(0.01)	
H Electricity	-0.07***		0.39***	
	(0.00)		(0.01)	
Individual	0.06***		-0.19***	
	(0.00)		(0.02)	
Nonprofit	-0.09***		0.49***	
	(0.01)		(0.01)	
University	-0.20***		0.58***	
	(0.01)		(0.02)	
Government	-0.14***		0.46***	
	(0.01)		(0.02)	
Hospital	-0.25***		0.57***	
	(0.06)		(0.08)	
Public-private cooperation	-0.06***		0.30***	
	(0.01)		(0.02)	
Non-EU27 co-applicants	-0.09***		0.17***	
	(0.01)		(0.04)	
Per capita GDP	0.00***	0.00**	0.00***	0.00**
	(0.00)	(4.51)	(0.00)	(4.21)
sHTE	0.05***	0.20**	0.41***	0.28**
	(0.02)	(2.97)	(0.06)	(6.64)
GERD	0.00***	0.00**	-0.00***	-0.00**
	(0.00)	(10.52)	(0.00)	(3.42)
sBFRD	-0.12***	-0.51**	-0.45***	-0.31**
	(0.01)	(9.16)	(0.05)	(8.28)
sHERD	0.02	0.08	-0.51***	-0.35**
	(0.03)	(0.79)	(0.10)	(5.22)
sBFRD x Public-private cooperation	-0.01	-0.04	1.78***	1.21**
	(0.14)	(0.07)	(0.27)	(6.59)
sHERD x Public-private cooperation	-0.38	-1.60	2.26***	1.53**
	(0.26)	(1.44)	(0.40)	(5.68)
Constant	-2.41***		-3.51*	
	(0.48)		(2.06)	
Inflation constant	-4.98***		0.24***	
	(0.04)		(0.01)	
Ln α	-3.20***		-0.25***	
	(0.02)		(0.02)	
Observations	563,360	563,360	563,360	563,360
Zeros	17,391		440,620	
Log likelihood	-1,127,824		-451,567	
χ2	18,399		78,533	
Prob>χ2	0.00		0.00	

*** Significant at 1%. ** Significant at 5%. *Significant at 10%. Robust standard errors below coefficients. *Company* is the benchmark for institutional types. Weight variable: share of number of applicants. Vuong statistic shows prefernce against stardard negative binomial. No multicollinearity accroding to individual and mean VIFs.

Fig. 1 EPO patents in 1990-2007 from Patstat

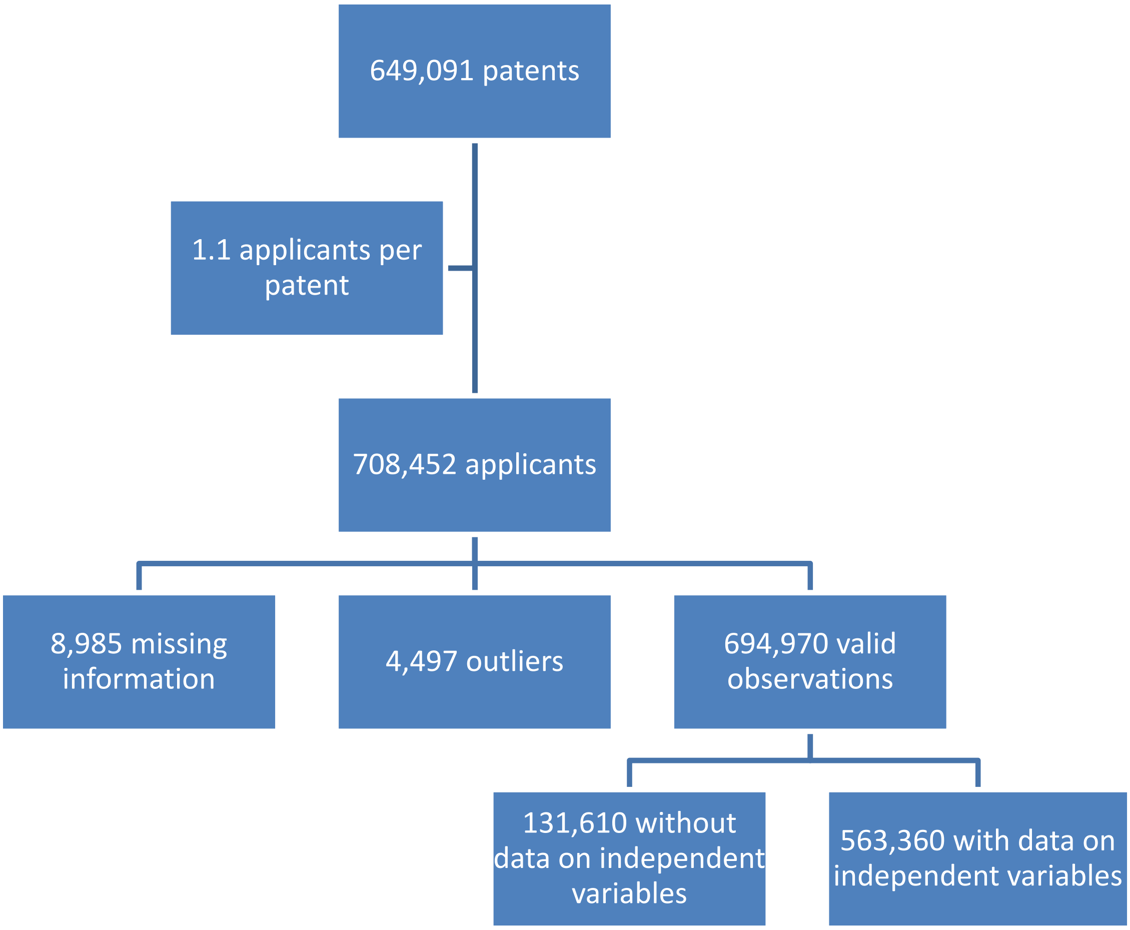
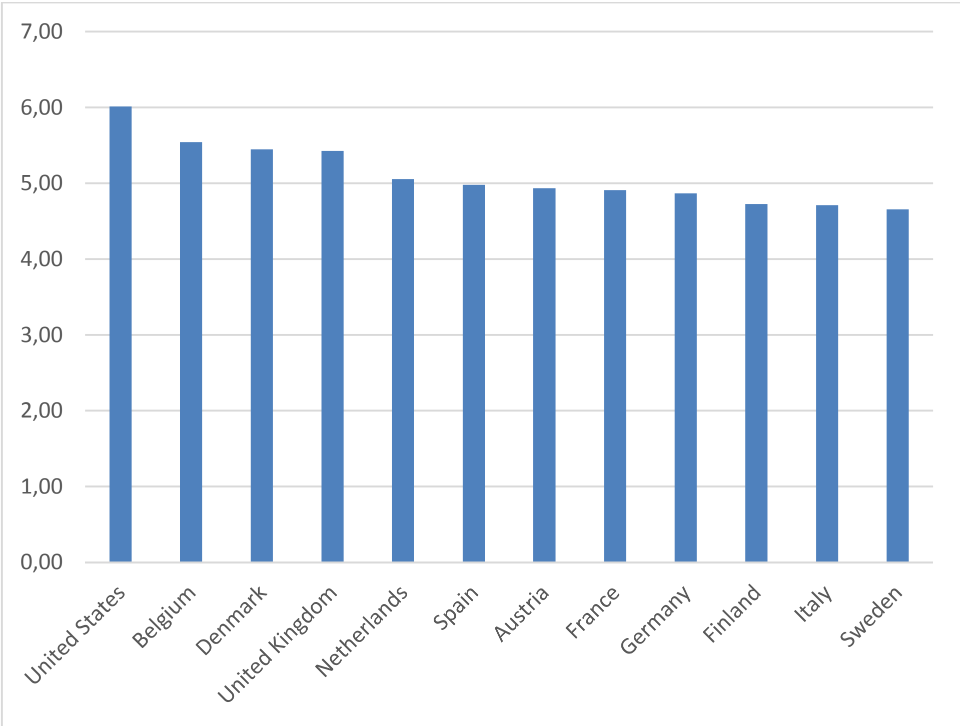


Fig. 2 Mean number of references per patent in the top applicant countries (n= 563,360)



Countries with at least 1% of total number of patent applications (over 4,500 each). Jointly they apply for 98% of all patents (45%. Germany, 53% the rest).