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Global markets for technology: Evidence from patent transactions

Antonio De Marco[a], Giuseppe Scellato[a,b,*], Elisa Ughetto[a,b], Federico Caviggioli[a]

[a] Politecnico di Torino, Corso Duca degli Abruzzi 24, 10129 Torino, Italy
[b] BRICK, Collegio Carlo Alberto, Via Real Collegio 30, 10024 Moncalieri, Italy

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ABSTRACT

The paper analyses the recent evolution of international markets for technology by examining changes in ownership of US granted patents. We study the effects of the geographical origin of patents, proxied by their first priority country, on the probability of patents being traded, on the timing of the transaction and on the probability of observing a cross-border transaction, while controlling for the characteristics of the patents, the time and sector specificities. The analyses are based on a comprehensive dataset that covers all the patents granted by the USPTO over the 2002–2012 period. The data from the US patent reassignment database have been cleaned and processed and a subset of 95,542 granted patents that have been traded has been identified. We obtain evidence from survival models that there has been an increase in the rate of patent transactions in recent years. The obtained results indicate that patents with a first non-US original applicant have less probability of being traded and show a longer time to transaction than US first priority patents. We also find that more science-based patents, which are usually characterized by a higher technological uncertainty, are more likely to be traded, but are much less likely to be involved in cross-border deals. The results are discussed in light of the impact of asymmetric information and search costs on international patent transactions.

1. Introduction

An increase in the internationalization of research and development (R & D) and inventive activities has been documented in recent years (Castellani and Peri, 2013; Guellec and van Pottelsberghe de la Potterie, 2001; Lewin et al., 2009; Narula and Zanfei, 2005; Picci, 2010), together with a progressive increase in patenting rates. The rising number of patent applications throughout the world can be explained by considering the emergence of complex technologies that often require pools of interdependent patents to be legally protected (e.g. in such fields as software, semiconductors and mobile communications).

These trends have contributed to the recent expansion of the markets for technology, in which patents are increasingly conceived as tradable assets (Arora et al., 2001; Arora and Gambardella, 2010; Benassi and Di Minin, 2009; Cockburn et al., 2010; Monk, 2009). Although globalization has facilitated the internationalization of R & D, it has been shown that innovative activities and technology trade are still predominantly national in scope (Alcacer et al., 2007; De Rassenfosse et al., 2010; Drivas and Economidou, 2015; Picci, 2010). Three levels of uncertainty that characterize technology deals have been found to greatly limit the geographical reach of technology trade, and are responsible for the dominant role of nearness in patent transactions: uncertainty about the property rights, about the value of the technology and about the patent trading process (Arora and Gambardella, 2010). All these types of uncertainty tend to be more pronounced when technology trade takes place across national boundaries.

Patent transactions can take the form of transfers, sales (outright sales or through auctions) or licensing agreements, depending on whether or not patent ownership is transferred.[1] While there is considerable anecdotal evidence that competitive challenges are leading firms to increasingly adopt new intellectual property (IP) strategies and to play an active role on the markets for patents (Monk, 2009), empirical evidence on patent trade is still scant. Most of the prior studies focused on licensing agreements (Alcacer et al., 2007; Arora and

* Corresponding author at: Politecnico di Torino, Corso Duca degli Abruzzi 24, 10129 Torino, Italy.
E-mail address: giuseppe.scellato@polito.it (G. Scellato).

[1] Although there is anecdotal evidence that a non-negligible fraction of patents is traded, it is difficult to accurately quantify the volume of such transactions. In fact, most exchanges of patents occur under conditions of utmost secrecy, through private bilateral transactions in which the terms of the negotiated agreement (often a licensing or cross-licensing agreement) are not disclosed to prevent sensitive information from leaking to competitors (Caviggioli and Ughetto, 2013). A few scientific attempts have been made to quantify the size of the market for technology. It has been estimated that in the mid-1990s, the market for technology was globally approximately $35–50 billion (Arora and Gambardella, 2010). Athreye and Cantwell (2007) reported that licensing revenues accounted for nearly $100 billion worldwide between 1950 and 2003 (although these figures would be considerably smaller if transactions among affiliated entities were excluded, as noted by Arora and Gambardella, 2010). Moreover, Kulatilaka and Lin (2006) also showed that worldwide revenues from patents increased from $15 billion in 1990 to $100 billion in 2000.

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Ceccagnoli, 2006; Arora and Fosfuri, 2003; Gambardella et al., 2007; Motohashi 2008 among others) and only a few recent papers have started to study transactions that involve the sale of patent rights, considering either data on patent auctions (Caviggioli and Ughetto, 2016; Fischer and Leidinger, 2014; Nair et al., 2011; Odasso et al., 2015; Sneed and Johnson, 2008) or on patent reassignments (Drivas and Economidou, 2015; Figueroa and Serrano, 2013; Galasso et al., 2013; Serrano, 2010,2013).

The way geographical factors affect technological flows and knowledge diffusion has been under-investigated in this literature, except for a few exceptions (Burhop and Wolf, 2013; Drivas and Economidou, 2015). In fact, the interplay between geographical origin and technology trade is still not clearly understood, due to a lack of data on trading rates. Hence, the question of whether geographic proximity between buyers and sellers can alleviate the information asymmetries and uncertainty entailed by the markets for technology has largely remained unanswered. In this paper, we provide an empirical analysis that is based on the elaboration of data on patent sales, in which the licensing channel has been excluded, and we explore the international dimension of the phenomenon. We analyze the recent evolution of the international markets for technology by examining changes in ownership of US granted patents. Moreover, we study the effects of the geographical origin of patents, as proxied by their first priority country, on the probability of patents being traded, on the timing of the transaction and on the probability of patents being cross-border traded, while controlling for the characteristics of the patents, the time and sector specificities. The analyses are based on a comprehensive dataset that covers all the patents granted by the USPTO in the 2002–2012 period. Data from the US patent reassignment database has been used and a data cleaning method has been applied that has led to the identification of a subset of 95,542 granted patents that have been traded.

We are in particular interested in understanding whether US patents, filed by companies based in countries other than the US, show different trading patterns from the patents filed by US companies, in order to provide a picture of the international dimension of the market for technology. We exploit the information on the patents originated from such geographical areas and their extension to the US to highlight the presence of patterns related to the uncertainty on the commercial value of the traded patents and to the presence of information asymmetries between patent owners and potential buyers. We expect that patents with a non-US origin will show less probability of being traded on the US market than patents with a US origin. To further explore this issue, we single out patent characteristics that might proxy the degree of asymmetric information that eventually affects the trading of patents in an international arena. We assume that patents covering innovation in emerging or immature technologies are exposed to a higher level of technological uncertainty and asymmetric information about their actual technological and economic value. Since the assessment of the true technical potential of a patented innovation requires substantial resources, proximity may play a significant role in relaxing such a constraint.

An important contribution to patent reassignments was provided by Serrano (2010), who analyzed the bibliographic characteristics and types of patentees of US patents traded between 1980 and 2001. We extend the work of Serrano (2010) in three ways. First, we look at more recent years (from 2002 to 2012), while Serrano's paper was based upon the 1980–2001 period. This temporal extension is important because the last decade witnessed an upsurge of patents with unclear scope that have led to legal disputes and to the emergence of non-practicing entities as major players on the market for technology. Second, we also focus our analysis on the international dimension of patent trading, as described above. Third, we also improve the adopted methods by refining and adding new criteria that can be used to identify the patent transactions that involve an actual change of ownership, while the cases that result from the merger and acquisition (M & As) of companies have been dropped.

We obtain evidence from survival models that there has been an increase in the rate of patent transactions in recent years. These results indicate that US granted patents with a first priority other than the US have less probability of being traded and show a longer time to transaction than US first priority patents. We also find that more science-based patents, which are usually characterized by a higher technological uncertainty, are more likely to be traded, but at the same time are much less likely to be involved in cross-border deals. All the estimates remain robust after the introduction of a wide range of controls at the patent, technology field and time levels.

The remainder of the paper is organized as follows. Section 2 discusses the background literature. Section 3 introduces the data, describes the explanatory variables used in the empirical analysis and provides some relevant descriptive statistics. Section 4 presents the econometric models and discusses the implications of the results on the understanding of the dynamics of international markets for technology. Section 5 concludes and summarizes the paper.

2. Background literature

In the "Markets for technology" sub-section, we review the literature that discusses the effects of technology trade on the innovation system as a whole, the reasons for engaging in patent transactions, and the works which have specifically focused on patent reassignments. In the "Asymmetric knowledge and the geography of technology trade" sub-section, we summarize the studies that have explored the factors that can limit the geographical reach of technology trade to a great extent and which affect the dynamics of trade on the markets for technology: the presence of information asymmetries between sellers and buyers, the uncertainty about the property rights, about the value of the technology and about the patent trading process. The limited number of studies that bridge the issues raised in both strands of literature in the context of intellectual property rights (IPRs) has inspired the contribution of our paper, which has in particular drawn upon the reviewed studies presented hereafter.

2.1. Markets for technology

Markets for technology have recently attracted both academic and policy interest. One stream of literature has discussed the effects of technology trade on the innovation system as a whole. It has been suggested that technology trade generates private and social gains, by reallocating patent rights to firms that are better at commercializing the patented innovation because of superior manufacturing and marketing capabilities (Arora et al., 2001; Gans et al., 2008; Teece, 1986) and at preventing patent disputes from ending up in court (Galasso et al., 2013). Patent trade improves the overall welfare and innovation, as it enhances innovation activity, knowledge diffusion and the emergence of specialized inventors, by stimulating the geographic spread of technology (De Rassenfosse et al., 2016; Drivas and Economidou, 2015; Lamoreaux and Sokoloff, 2001; Spulber, 2008). Patent trade allows knowledge to reach where it may best be used, and to be directed toward firms with superior manufacturing and marketing capabilities (Arora et al., 2001; Gans et al., 2008; Teece, 1986). Firms that pursue innovation strategies through an active acquisition of patents have the opportunity of accessing complementary technologies and of fostering their innovation capacity. However, concerns have been raised about patents that have been acquired for strategic or opportunistic reasons, and which thus adversely affect the innovation activity of other firms. In this regard, the rising role of non-practicing entities (also called patent trolls) on the markets for technology has been regarded with suspicion, because of their practice of extracting excessive licensing fees from manufacturing firms or of engaging in frivolous infringement litigation (Bessen and Meurer, 2014; Caviggioli and Ughetto, 2016; Lemley and Shapiro, 2007; Reitzig et al., 2007).

Other academic works have investigated the reasons for engaging in patent transactions, by focusing on licensing. Scholars in the industrial economics and strategic management fields have identified strategic issues, such as blocking entry and the identification of the technology as a de facto standard in industries characterized by strong network externalities, as major factors in the trading of patents (Arora and Fosfuri, 2003; Fosfuri, 2006; Gallini and Winter, 1985 among others). Other explanations have been offered that refer to the inability of firms to exploit the patented innovation (Arora and Fosfuri, 2003), to the presence of structural weaknesses (Arora and Ceccagnoli, 2006; Teece, 1986) and to the intrinsic characteristics of the patented technology, such as its value, obsolescence and generalizability (Gambardella et al., 2007; Teece, 1986). Among all these factors, it seems that the motives that drive the decisions to engage in patent transactions the most are related to the demand side and to strategic behavior (see Caviggioli and Ughetto, 2013 for a recent survey on these issues). In fact, the market for patents introduces important changes to corporate competitive dynamics, as it allows firms to use patents as strategic tools or as valuable assets that can be monetized to generate income (Caviggioli and Ughetto, 2013; Odasso and Ughetto, 2011; Monk, 2009).

Patent transactions, in the form of licensing agreements, sales or transfers, have been studied in a limited number of empirical works, due to the lack of comprehensive datasets and to the paucity of information on the contractual terms of such transactions. Researchers have recently begun to investigate the transactions that involve the sale of patent rights, by exploiting either data on patent auctions (Caviggioli and Ughetto, 2016; Fischer and Leidinger, 2014; Nair et al., 2011; Odasso et al., 2015; Sneed and Johnson, 2008) or on patent reassignments (Drivas and Economidou, 2015; Figueroa and Serrano, 2013; Galasso et al., 2013; Serrano, 2010,2013). The main results of the papers that have exploited data on patent reassignments, and which are closer to the scope of our work, are briefly outlined hereafter.

The paper that paved the way for this new literature is the one by Serrano (2010). Serrano, who was the first to use data on changes in patent ownership taken from the USPTO, documented the effects of different types of patentees, technology fields and patent bibliographic characteristics on the sale of patents over the 1980–2001 period. He showed that individual private inventors and small innovators are the most active sellers of patents, whereas government agencies and large innovators are the least active. In addition, younger, frequently cited, and more original patents are more likely to be traded.

In a subsequent work, Figueroa and Serrano (2013) studied to what extent patent trading flows are affected by the fit between the original patentee's patent portfolio and the patented invention, as well as by the complementarity between the buyer's technological profile and the patented invention. Their findings show that small firms sell and acquire more patents than large firms do, and that patent trade has not led to an excessive concentration of patent rights in the hands of large firms. Moreover, the lower the fit of the patent to the patentee's patent portfolio is, the higher the likelihood of the patent being sold, the higher the match between the buyer's technological capability and the patented invention, and the higher the probability of the patent being acquired by a small buyer.

The studies by Galasso et al. (2013) and Serrano (2013) quantified the gains from trade in patents, in terms of patent enforcement and comparative advantages for small firms, respectively. Galasso et al. (2013), matching information on patent trades and litigation on patents owned by individual inventors in the US during the 1983–2000 period, found that patent transactions are affected to a great extent by the adopted tax policy. In addition, Galasso et al. (2013) found that patents subject to changes in ownership on average have less probability of subsequently being litigated, although this effect is only relevant for patents sold by individual inventors to firms with larger patent portfolios. Serrano (2013) suggested that the market for patents generates significant gains from trade for small firms (accounting for about ten percent of the value of the volume of the trade of patents), and that lowering market transaction costs by fifty percent increases such gains by an additional ten percent. However, since the distribution of the gains from trade is skewed, only a small fraction of traded patents accounts for a large share of realized gains.

2.2. Asymmetric knowledge and the geography of technology trade

Some recent works on market design (Roth, 2007, 2008) have highlighted that markets operate efficiently when three conditions are met: i) buyers and sellers have opportunities to trade with a wide range of potential transactors (i.e. market thickness), ii) there are always opportunities to access alternative options in the marketplace before trade takes place (lack of congestion) and iii) market conditions allow participants to reveal their preferences and types without the risk of undermining their bargaining power or allowing hold-ups (i.e market safety).

Gans and Stern (2010) applied this analysis framework to the trading of ideas and technology. Although some attempts to create formalized IP exchange markets have been made (e.g. patent auctions), markets for technology are still characterized by a lack or limited availability of the above-mentioned features. The presence of information asymmetries between sellers and buyers, the importance of uncertainty about the commercial value of the technology, the relevance of the search costs and the possibility of opportunistic behavior all have a profound effect on the dynamics of trade on the markets for technology (Arora and Gambardella, 2010). Jensen et al. (2015) showed that proximity, in terms of trust and personal familiarity, leads to an increase in trade on the market for technology. Language barriers and geographical distance further complicate the asymmetric knowledge problems that are already pervasive on these markets, and impose additional obstacles in terms of transfer of non-codified knowledge and the design and enforcement of contracts (Buenstorf and Geissler, 2012).

Overall, it has been suggested that technology markets do not function efficiently and are affected by several frictions, ranging from high search and transactions costs to the lack of market thickness (Arora et al., 2001; De Rassenfosse et al., 2016; Gans and Stern, 2010). In addition, the commercialization of patented inventions is complicated by the presence of information asymmetries between sellers and buyers, by the uncertainty on the commercial value of the technology and by the difficulty of transferring the non-codified knowledge that underlies the traded technology (Agrawal, 2006). Although globalization has facilitated the internationalization of R & D, it has been shown that technology trade is still predominantly national in scope (Alcacer et al., 2007; De Rassenfosse et al., 2010; Drivas and Economidou, 2015; Picci, 2010).[2]

The ability to assess the commercialization prospects of an invention is crucial for firms in order to gain a strategic advantage in a transaction. However, the knowledge related to an invention tends to be complex and imperfectly codified (Agrawal, 2006). Therefore, firms often devote considerable resources, in terms of time and money, to the acquisition of relevant information on the commercial value of the technology and on the deal. The collection of such relevant information is facilitated by geographical proximity. Moreover, a potential buyer might be interested in developing close connections with the seller in order to implement the patented technology. The transfer of know-how between the parties involved in a transaction is favored by geographical closeness (Arora and Gambardella, 2010; Gans et al., 2008). The possibility of having easier access to knowledge of the technology that has to be bought because of geographical vicinity leads to the alleviation of uncertainty and asymmetric information about the extent of the property right. As a result of this, as Gans et al. (2008) showed, when a US

[2] Drivas and Economidou (2015) estimated a gravity model to explore whether patent trades are confined by geographic factors and to what extent the importance of geography has changed over time due to technological developments. They found evidence of a notable localization of patent transactions, since states tend to be more involved in exchanging patents within their borders than with other states or countries.

patent is licensed, the licensing generally takes place within a narrow window around the date in which the patent is granted by the US Patent Office. Another benefit of localization of patent transactions on the same market of reference as the invention is that the detailed knowledge of the market on which firms currently operate allows them to better avoid opportunistic behavior and to be more knowledgeable about the market prospects of the technology, which in turn lower the uncertainty about the patent trading process.

3. Data

3.1. Sample and method

We made use of a comprehensive dataset covering all of the 1,910,163 patents granted by the USPTO over the 2002–2012 period. The basic data on patents were extracted from the Google USPTO bulk download webpage.[3]

When a patent right is transferred, an assignment is recorded at the USPTO in the Patent Assignment database. An assignment is a transfer, by a seller to a buyer, of the rights, title and interest in one or more granted patents or patent applications. Although patent owners are not required to disclose patent transactions to the USPTO, they are offered incentives to do so for legal reasons. In fact, Section 261 of the U.S. Patent Act states that patent owners facing litigation in court are only protected against subsequent assignments if they have recorded the transfers of patents at the USPTO.

The database records, for each assignment, the name of the buyer (i.e. assignee) and of the seller (i.e. assignor), the date at which the assignment was recorded at the USPTO, the date at which the private agreement between the parties was signed and the associated patent number (or patent application number). The database also reports the rationale behind the transfer of the patent (i.e. conveyance type). This field is useful for data cleaning because it allows changes in ownership (recorded as "assignment of assignors' interest") to be distinguished from other administrative events (e.g. the union of commercial interests as a "merger", the securitization of a patent as collateral for a "security interest/agreement", the change of name or address of its current owner as a "change of name/address", the corrections of previous mistakes as a "corrective assignment"). However, the "conveyance type" field cannot be used as a reliable identifier of actual changes in ownership because first assignments and cases of M & A or corrections are sometimes labelled as "assignment of assignor interest".

An algorithm, based on the comparison between information on inventors and assignees at the granting date and information on the buyers and sellers at the transaction date, was set up in order to improve the identification of real changes in ownership. We adopted Serrano's (2010) approach and applied further technical refinements. First, we employed four kinds of string matching heuristics (simple ratio, edit distance, tokenization of words, best partial) that are robust to different constructions of individual and company names (i.e. missing letters, the presence of sub-strings, out-of-order issues, etc.). These procedures were then used to score the similarity of all the possible comparisons between all the inventors and patent sellers, as well as between all the assignees and patent buyers. The thus developed technique should be more reliable for identifying redundant assignments whenever the recorded ordering of the individuals and firms in the database matters for the outcome of the comparison.

Three distinct steps were followed to accurately identify a real transfer of ownership from other types of events. First, we removed assignments that had taken place between the inventors and the organization they worked for (i.e. first assignments). In the US patent system, inventors rather than organizations act as patent applicants. Hence, first assignments do not represent a real change of ownership. From an initial dataset of 3,023,853 transactions (including both first-assignments and reassignments), we were left with a total of 268,043 transactions. Second, we further cleaned the sample by removing: i) records in which the buyer and the seller were the same organization, ii) cases in which the transaction date was reported either before the application date or after the expiration of the patent. Third, we dropped the transactions that originated as the result of administrative events, such as a change in name and address, and any corrective assignments that amended previous information recorded in the database.

However, the mere exclusion of the "merger" conveyance type proved to be insufficient, because several transactions following M & As had not been properly recorded in the database.[4] In order to deal with this issue, we adopted additional criteria: first, we analyzed the distribution of the average bundle size for both the patent transactions classified as "mergers" and the remaining patent transactions. In line with the expectation that the M & As of companies usually involve the exchange of bundles of patents, we found that a small number of patent transactions labelled as "merger" were associated with a single patent. We then performed a random sampling and a manual checking of the transactions that involved patents traded in bundles, adopting various thresholds in terms of bundle size. It was found that 55.92% of the sample patents involved just one patent and almost 71% were associated with bundles of up to 10 patents. Therefore, we decided to drop all patents traded in large sized bundles (i.e. equal to or more than 11 patents). Indeed, we manually screened a sample of transactions that involved more than 10 patents but which did not report the "merger" conveyance type. The obtained results confirmed that the inclusion of these records could generate noise in the data, as they all resulted to be transactions that were related to M & As. After this cleaning, we ended up with 95,541 (5%) traded patents (that had been traded in bundles of no more than 10 patents) over the 2002–2012 period.[5]

We are well aware of the fact that adopting such a method to identify traded patents could lead to the exclusion of some large patent portfolio deals that simultaneously involve the sale of hundreds of patents (e.g. the $4.5 billion acquisition of the Nortel Networks' patent portfolio, which involved 6000 patent applications, or the acquisition of Eastman Kodak's patent portfolio in 2012 made up of 1100 digital-imaging patents) from the analysis. However, the aforementioned cases represent clear outliers and were not the focus of our empirical setting.

3.2. Variables and descriptive statistics

Figs. 1 and 2 illustrate the trends of traded patents (total and broken down according to the country of origin) over the considered time frame. Fig. 1 reports an increasing trend in the change of ownership for the sample of patents granted between 2002 and 2010. The data are plotted according to the transaction year and the chart distinguishes between patents with a US priority and those with a non-US priority. It should be noted that recent years can be affected by truncation. Fig. 2 provides further details on the share of traded patents by main geographical areas. It can be observed that US priority patents cover the largest area in the chart, and this is followed by EPC priority patents.

[3] The patent assignment and granting data were downloaded through a Python script, iteratively executing CURL requests to specific URLs in order to fetch a list of ZIP files. The patent assignment and granting data were fetched, parsed and recorded in a MYSQL database through a set of Python routines. Several data inconsistencies (file headings, opening and closing XML tags) were subsequently fixed, and various regular expressions were implemented in order to identify different organization types (i.e. firms, universities) and standardized assignee and inventor names (e.g. by removing accented letters and special characters).

[4] Analyzing the patents related to a random sample of 90 firms (with 475 patents) that were acquired in 2004, Lerner and Seru (2015) reported that only about 50% were reassigned to the buyer or reassigned as part of a noted "merger" in the USPTO dataset.

[5] Our result differs from the finding of Serrano (2010), who reported that 13.5% of all US patents granted during the 1980–2001 period have been traded at least once over their life cycle. Such a difference is determined by the more stringent criteria we applied to identify traded patents: we in fact excluded all the transactions that involved more than 10 patents, as they were considered to be associated with M & A activities rather than a mere transfer of ownership.

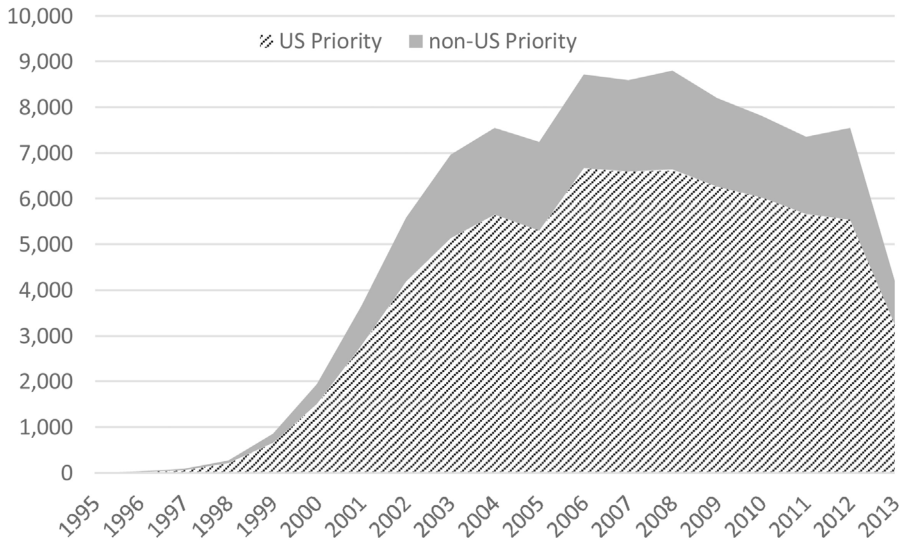

Fig. 1. Number of traded patents (by transaction year) within the sample of patents granted between 2002 and 2010. The areas distinguish between patents with a US priority and those with a non-US priority. Recent years can be affected by truncation.

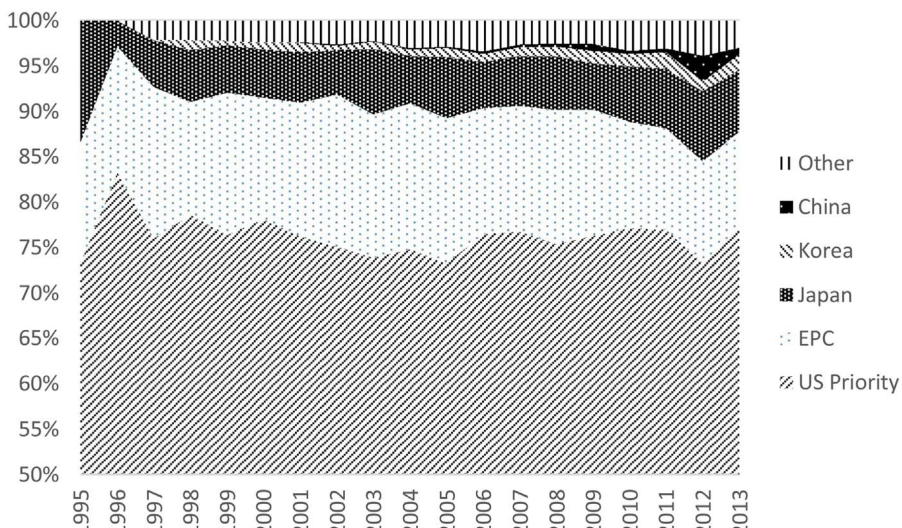

Fig. 2. Share of traded patents from the main geographical areas (on the basis of the transaction year). EPC includes countries that belong to the European Patent Convention.

Table 1
Number of total and traded patents granted between 2002 and 2010 by priority country.

Priority country	Granted patents	Traded patents	%
The United States	1,135,313	72,308	6.37%
EPC	241,345	13,292	5.51%
Japan	387,790	5,714	1.47%
Korea	77,005	1,044	1.36%
China	15,307	470	3.07%
Other countries	53,403	2,713	5.08%
TOTAL	**1,910,163**	**95,541**	**5.00%**

Table 1 illustrates the number and percentages of traded patents on the basis of the first priority country. The highest incidence of transactions is recorded for US priority patents (6.37%), and this is followed by EPC priority patents (5.51%). China, Japan and Korea show a lower percentage incidence of traded patents (3.07%, 1.47% and 1.36%, respectively). Table 2 reports the number and percentages of traded patents by industrial sector.[6] The highest incidence of traded patents is found in the "Pesticides, agro-chemical products" sector (8.70%), and this is followed by "Medical equipment" (7.95%), "Weapons and ammunition" (7.87%) and "Pharmaceuticals" (7.46%). The lowest incidence values of traded patents are in the "Electric distribution, control, wire, cable" (2.89%), "Electronic components" (2.93%)[7] and "Electric motors, generators, transformers" (3.49%) fields. The same Table reports the share of traded patents with a US priority: the fields are characterized by heterogeneity, since the share ranges from 62% for the "Electronic components" field to 88% for the "Furniture, consumer goods" field.

Table 3 reports the decomposition of trading flows of US granted patents according to the priority country and country of the buyer. The data indicate that 72.2% of US granted patents with a national priority involve a domestic deal. As expected, domestic deals are the most frequent ones; however, a non-negligible number of cases also involve cross-border transactions. The percentage of cross-border trade for patents with Japanese and German priorities is 32.1% and 36.3%, respectively. Interestingly, patents with a UK first priority exhibit a relatively higher proportion of cross-border trade (60.3%).

Table 4 reports the definition of the explanatory variables used in

[6] The classification is based on the concordance Table presented in Van Looy et al. (2014).

[7] It should be noted that the low incidence of transactions in the Electronics field could in part be due to the fact that only patents traded in bundles no larger than 10 have been considered.

Table 2
Number of total and traded patents granted between 2002 and 2010 by industrial sector (based on the concordance table in Van Looy et al., 2014), and percentage of traded patents with a US priority.

Industrial sector	Granted patents	Traded patents	% of traded on total granted	% of US priority patents on traded
Pesticides, agro-chemical products	13,237	1,151	8.70%	69.77%
Medical equipment	99,724	7,927	7.95%	82.23%
Weapons and ammunition	6,290	495	7.87%	86.26%
Pharmaceuticals	124,575	9,298	7.46%	68.20%
Agricultural and forestry machinery	15,064	1,009	6.70%	83.15%
Food, beverages	13,978	887	6.35%	72.49%
Furniture, consumer goods	53,579	3,370	6.29%	87.80%
Non-metallic mineral products	45,829	2,844	6.21%	73.84%
Non-specific purpose machinery	52,157	3,185	6.11%	74.79%
Basic metals	20,329	1,234	6.07%	69.04%
Rubber and plastic products	50,199	3,005	5.99%	77.60%
Paper	5,705	327	5.73%	74.62%
Special purpose machinery	90,208	5,094	5.65%	72.83%
Fabricated metal products	38,988	2,187	5.61%	79.56%
Basic chemical products	89,392	4,904	5.49%	64.95%
Domestic appliances	30,061	1,582	5.26%	78.70%
Other electrical equipment	30,599	1,600	5.23%	82.00%
Measuring instruments	110,651	5,707	5.16%	72.37%
Other chemical products	13,993	690	4.93%	70.43%
Other transport equipment	21,941	1,075	4.90%	77.58%
Lightening equipment	14,220	693	4.87%	73.45%
Signal transmission, telecommunications	216,071	10,262	4.75%	77.98%
Petroleum products, nuclear fuel	10,607	499	4.70%	72.14%
Machine-tools	37,558	1,752	4.66%	70.26%
Accumulators, batteries	14,899	669	4.49%	64.87%
Television and radio receivers, audiovisual electronics	59,793	2,661	4.45%	78.39%
Industrial process control equipment	17,656	770	4.36%	75.32%
Energy machinery	52,529	2,253	4.29%	69.51%
Office machinery and computers	416,226	17,580	4.22%	80.77%
Motor vehicles	87,118	3,633	4.17%	76.05%
Optical instruments	69,098	2,812	4.07%	70.70%
Electric motors, generators, transformers	17,976	627	3.49%	68.74%
Electronic components	184,961	5,426	2.93%	61.91%
Electric distributions, controls, wires, cables	36,175	1,046	2.89%	73.14%
Other fields	20,606	1,183	5.74%	76.16%

Note: each single patent can be associated with multiple sectors.

the empirical analysis and the related descriptive statistics. Several bibliometric patent variables that are commonly employed in the analysis of patent databases as proxies of innovation and technological dimensions were collected.[8] In order to investigate the relevance of asymmetric information that could affect patent trading in an international context, we operationalized the degree of technological uncertainty by means of an indicator based on the number of backward citations to the non-patent literature. Since backward citations show a heterogeneous distribution over different technological areas, we constructed the distribution of backward non-patent citations according to the technological domain (defined using three-digit level International Patent Classification – IPC codes-which resulted in approximately 600 classes) using all the US patents granted over the considered time

[8] See van Zeebroeck and van Pottelsberghe de la Potterie (2011) for a review.

Table 3
Trading flows of US granted patents by priority country and country of the buyer (%).

Priority country	Country of the buyer	%
The United States	The United States	72.2%
	Canada	3.7%
	Japan	3.3%
	Germany	1.5%
	Taiwan	1.5%
	Others	17.8%
Japan	Japan	67.9%
	The United States	16.9%
	Samoa	2.8%
	Germany	2.0%
	South Korea	1.2%
	Others	9.2%
Germany	Germany	63.7%
	The United States	13.7%
	Switzerland	3.8%
	Japan	2.2%
	France	1.8%
	Others	14.7%
The United Kingdom	The United Kingdom	39.7%
	The United States	27.6%
	Germany	4.7%
	Switzerland	4.0%
	The Netherlands	1.7%
	Others	22.3%

interval. Then, we defined a “technological uncertainty” dummy variable which, for each analyzed patent, was equal to 1 if its number of backward non-patent citations fell into the 90th percentile of the distribution in the related technological field.

4. Econometric results

In this Section, we examine the effect of the geographical origin of patents and of their degree of technological uncertainty on the probability of patents being traded, on the timing of the transaction and on the probability of observing a cross-border transaction, controlling for the characteristics of the patents, the time and sector specificities. The US granted patents with a first priority in any EPC member country, in Japan, Korea and in China, are compared in all the models with the group of patents with first priority filing in the US. Since the aim is to test the hypothesis that information asymmetries, search costs and uncertainty about the quality of the patented technology should be higher for international patent transactions than for domestic patent transactions, we have included the “technological uncertainty” variable, based on the number of backward citations to the non-patent literature, in all the model specifications.

4.1. Determinants of patent transactions

We first analyze to what extent the likelihood of observing a patent transaction is affected by the geographical origin of patents through a probit model. The probit model[9] is run on the whole sample of US granted patents (traded and not traded), and the dependent variable (TRADED) is equal to 1 if the patent has been traded, and 0 otherwise. The aim of the probit model is to test whether patents with a first priority other than the US have less probability of being traded than US first priority patents. The effect of first priority countries is tested by including dummy variables for Japan, all of the EPC countries, Korea, China and other geographical areas, in addition to the bibliographic characteristics of the patents, and the results are shown in Table 5. The excluded category is the group of patents with a first priority filing in the US. We introduce a dummy into the models that equals 1 if a PCT

[9] The model was estimated with the “probit” routine of STATA 13.1.

Table 4
List of variables used in the empirical analysis and descriptive statistics.

Variables	Definition	Mean	Median	Std.dev.
Claims	Number of patent claims	16.143	15	9.533
Inventors	Number of patent inventors at the granting date	2.496	2	1.655
IPC4	Number of IPC 4 digit subclasses	1.269	1	0.63
PCT dummy	Dummy variable equal to 1 if the PCT procedure has been followed	0.368	0	0.482
Backward cit. (patent)	Number of patent backward citations (logarithm)	2.627	2.565	0.88
Technological uncertainty	Dummy variable equal to 1 if the number of backward non-patent citations falls into the 90th percentile of the technological field of the patent (identified considering the IPC classes)	0.081	0	0.273
Forward cit.	Number of forward citations (logarithm)	1.561	1.609	1.176
Time to granting	Number of months between the date of filing and the date of granting (logarithm)	3.541	3.575	0.511
US priority	Dummy variable equal to 1 if the patent has a US priority and 0 otherwise	0.594	1	0.491
EPC priority	Dummy variable equal to 1 if the patent has a priority in one of the member states of the European Patent Convention and 0 otherwise	0.126	0	0.332
Japan priority	Dummy variable equal to 1 if the patent has a Japanese priority and 0 otherwise	0.203	0	0.402
Korea priority	Dummy variable equal to 1 if the patent has a Korean priority and 0 otherwise	0.04	0	0.197
China priority	Dummy variable equal to 1 if the patent has a Chinese priority and 0 otherwise	0.007	0	0.089
Other countries priority	Dummy variable equal to 1 if the patent has a priority in another country and 0 otherwise	0.028	0	0.165
Traded	Dummy equal to 1 if the patent has been traded	0.050	0	0.218
Time from Application to Transaction	Number of months between the filing date and the date of reassignment	108.877	110.133	40.978
From US to non-US[a]	Dummy variable equal to 1 if the patent has a first priority filing in the US and is purchased by a non-US firm and 0 otherwise	0.161	0	0.368

[a] The variable is calculated for the sub-sample of patents traded before granting.

Table 5
Probit model (marginal effects reported). Determinants of the likelihood of a patent being traded.

Dependent variable: **Traded**	Model 1	Model 2
Sample: **Granted patents**		
EPC priority	−0.0076***	−0.0076***
	(0.000)	(0.000)
Japan priority	−0.0419***	−0.0370***
	(0.000)	(0.000)
Korea priority	−0.0335***	−0.0296***
	(0.000)	(0.000)
China priority	−0.0139***	−0.0084***
	(0.001)	(0.002)
Other countries priority	−0.0065***	−0.0027***
	(0.001)	(0.001)
Inventors		−0.0023***
		(0.000)
Claims		0.0001***
		(0.000)
IPC4		−0.0001
		(0.000)
PCT dummy		0.0197***
		(0.000)
Technological uncertainty		0.0034***
		(0.001)
Backward cit. (patent)		0.0018***
		(0.000)
Forward cit.		0.0053***
		(0.000)
Technology field dummies	Yes	Yes
Grant year dummies	Yes	Yes
Observations	1,885,829	1,882,964
Chi2	28,155	34,933
Loglike	−356,798	−352,527
Pseudo R2	0.0446	0.0542

The dependent variable is "Traded", a dummy variable equal to 1 if the patent has been traded, and 0 otherwise. The excluded category is the group of patents with the first priority filing in the US. The sample is made up of all the granted patents. The marginal effect of each independent variable is reported while holding all the variables at their mean value; for dummy variables, dy/dx represents the discrete change from 0 to 1. Technology field and grant year dummies have been included in all the models (not reported for space reasons). The robust standard errors are in parenthesis. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.10$.

(Patent Cooperation Treaty) has been filed. The presence of a PCT application indicates that the potential final market of a specific patent covers a very large number of countries. Hence, we expect that, ceteris paribus, such patents would show a greater likelihood of being traded.[10] Model 1 is the baseline model, and it only reports the priority country dummies.[11] Model 2 adds several patent-level controls to proxy for the quality, scope, and complexity of the patents (and which might have an impact on their tradability), time and sector controls. The model also includes the measure of technological uncertainty, based on the number of backward citations to the non-patent literature. Marginal effects of explanatory variables are reported while holding all the variables at their mean value; dy/dx represents the discrete change from 0 to 1 for the dummy variables.

The analysis highlights that patents with a first priority other than the US have less likelihood of being traded than US first priority patents. The marginal effects, considering the probability baselines in the probit models (4.20% Model 1 and 4.08% Model 2), indicate that the phenomenon is relevant. For example, the dummy for the patents with a first priority in any EPC member state implies a reduction of 18.08% (Model 1) and 18.61% (Model 2) in the probability of a patent being traded, compared to US first priority patents. Relevant reduction percentages in the probability of a patent being traded are also found for patents with a first priority in China (33.13% Model 1; 20.57% Model 2).

The decisions concerning the international extension of patents (i.e. non-US firms patenting in the US) can be associated with two main factors. First, the US market might be relevant for foreign firms to

[10] A set of information about the filing process was collected for all of the analyzed patents: the presence of a PCT filing, the number of the INPADOC family members, and a dummy which showed whether the patent had European and Japanese equivalents (triadic). All of our models were tested with each of the three variables, and the results were found to be very similar; for the sake of brevity, we have only reported the results of the models that include the PCT dummy. As an additional robustness check, we also tested the model on a limited group of hi-tech fields, such as "Signal transmission, telecommunications", "Optical instruments", and "Office machinery and computers", and very similar results were found.

[11] Patents can be traded more than once during their lifetime. However, evidence has emerged in the considered sample that only 0.73% of all the granted patents report multiple changes of ownership. In this paper, just the first transaction is modelled. However, the analysis of this small but interesting sub-sample of traded patents might be an interesting avenue for future research. We would like to thank the anonymous reviewer who pointed out this possible extension of the current work.

produce and sell their patented products. Second, the international extension of a patent might be related to a strategy of external exploitation of the patent itself (either through a trade sale or a licensing agreement). If the latter motive prevails, a higher likelihood of transactions for patents with a non-US priority should be observed at the margin. The fact that a different pattern can be observed suggests that the costs incurred in evaluating patented technology might offset the potential benefits derived from cross-border patent trading, and that this can in turn restrain the global reach of the market for technology.

The "Technological uncertainty" variable reports a positive coefficient. Patents that protect inventions characterized by higher degree of uncertainty, measured as closeness to basic research, are more likely to be traded. This seems to be coherent with an explorative strategic role of the market for technology. The estimates also highlight that patents with a higher number of forward citations and of backward patent citations show a significant increase in the average likelihood of being traded, in a similar way to the results obtained by Serrano (2010). As expected, the PCT dummy has a positive significant impact on the likelihood of a patent being traded. Furthermore, patents with a higher number of claims and a lower number of inventors have a greater likelihood of being traded. These results could be interpreted in light of the arguments advanced in the literature on patent value. The number of claims is often associated with a higher patent scope (Harhoff et al., 2003; Lanjouw and Schankerman, 1997, 2004; van Zeebroeck and van Pottelsberghe de la Potterie, 2011), and with higher chances of a patent surviving an invalidation procedure (Caviggioli et al., 2013; Reitzig, 2003). Patents with a larger number of claims are therefore more likely to be traded, because of their greater legal sustainability and broader scope. The number of inventors proxies the research effort (Giuri et al., 2005; Guellec and van Pottelsberghe de la Potterie, 2000). The fact that research intensive and complex patents are less likely to be traded may reflect a dominant role, on the markets for technology, of non-practicing entities, which are more interested in the exclusion right than in the underlying technological content of a patent.

4.2. *Trends in patent transactions*

The previous analysis is complemented by estimating the determinants of the time to transaction, controlling for censored observations through a standard survival model. The aim of this modeling approach is to check the evidence found in Table 5, and to analyze the presence of significant trends in patent transaction rates over the past decade, net of censoring effects. The use of survival models is justified by the fact that patents applied in recent years are exposed to the "risk" of being traded for a shorter amount of time than patents applied in the past. Hence, it could be possible to underestimate the actual trend in the phenomenon if the censored observations are not controlled for. The survival model[12] is run on the whole sample of US granted patents (traded and not traded) and the dependent variable is represented by the number of months between the patent application date and the transaction date ("Time from Application to Transaction"). The results of the survival model (the coefficients of the underlying exponential model) are presented in Table 6. A positive (negative) coefficient means that the effect of increasing the considered covariate is an increase (decrease) in the sub-hazard and thus an increase (decrease) in the cumulative incidence function, which results in a shorter (longer) duration. The results show that patents applied in recent years (2009–2012) have a greater likelihood of being traded. In line with the results of the probit model, we find that patents with a first priority other than the US have longer duration than US first priority patents. The "Technological uncertainty" variable shows a significant positive sign, thus suggesting that higher levels of uncertainty are associated with a shorter duration. Patents with a higher number of inventors and a narrower technological scope are instead associated with a longer duration, as proxied by the number of IPC codes. This result suggests that patents that cover several technological fields can be traded more easily. Patents with an international dimension, and thus with a wider geographical scope, are correlated with a shorter duration. Instead, patents with a higher number of claims, forward citations and backward citations show shorter durations and consequently a greater likelihood of being traded, net of censoring effects.

Table 6
Survival model. Determinants of the time to transaction (from the application date), controlling for censored observations.

Dependent variable: **Time from Application to Transaction**	Model 1
Sample: **Granted patents**	
EPC priority	−0.2621***
	(0.010)
Japan priority	−1.2932***
	(0.014)
Korea priority	−1.1755***
	(0.032)
China priority	−0.1774***
	(0.047)
Other countries priority	−0.0616***
	(0.020)
Application years (2006–2008)	0.0417***
	(0.009)
Application years (2009–2012)	0.2248***
	(0.017)
Inventors	−0.0579***
	(0.002)
Claims	0.0016***
	(0.000)
IPC4	−0.0154*
	(0.009)
PCT dummy	0.3969***
	(0.007)
Time to granting	0.1612***
	(0.007)
Technological uncertainty	0.0669***
	(0.012)
Backward cit. (patent)	0.0253***
	(0.004)
Forward cit.	0.1195***
	(0.003)
Technology field dummies	Yes
Constant	−8.3910***
	(0.029)
Observations	1,882,964
Failures	93785
Loglike	−484663

The dependent variable is "Time from Application to Transaction", which is the time that passes from the patent application date to the transaction date (in months). The excluded category for the geographical origin is the group of patents with a first priority filing in the US. The reference category for the application period is represented by patents applied before 2006. Coefficients of the underlying exponential model are reported. A positive (negative) coefficient results in a shorter (longer) duration and hence a greater (lower) likelihood of observing a transaction. Technology field dummies have been included in all the models (not reported for space reasons). Standard errors are in parenthesis. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.10$.

4.3. *The timing of patent transactions*

A Heckman selection model is presented in Table 7 to examine the effects of the geographical origin of patents on the timing of the transactions. The objective of the analysis is in fact to test whether patents with a first priority other than the US have a longer time to transaction than US first priority patents. The Heckman selection model specification[13] assumes that there exists an underlying regression

[12] The model was estimated with the "streg" routine of STATA 13.1

[13] The model was estimated with the "heckman" routine of STATA 13.1

Table 7
Heckman selection model (second-stage equation). Determinants of the time to transaction (from the application date). Marginal effects reported.

Dependent variable: **Time from Application to Transaction**	Model 1
Sample: **Traded patents**	
EPC priority	2.7218***
	(0.382)
Japan priority	8.9598***
	(0.954)
Korea priority	9.8632***
	(1.351)
China priority	13.7036***
	(1.684)
Other countries priority	6.2411***
	(0.712)
Inventors	−1.0475***
	(0.085)
Claims	−0.0414***
	(0.012)
IPC4	0.1318
	(0.304)
PCT Dummy	−1.5877***
	(0.397)
Time to granting	16.5148***
	(0.269)
Technological uncertainty	−1.3342***
	(0.424)
Backward cit. (patent)	−0.6241***
	(0.146)
Forward cit.	1.3359***
	(0.143)
Technology field dummies	Yes
Grant year dummies	Yes
Constant	−13.9838***
	(4.066)
Observations	1,882,964
Athrho	−0.1744***
	(0.046)
lnsigma	3.5922***
	(0.007)

The dependent variable is "Time from Application to Transaction", which is the time that passes from the patent application date to the transaction date (in months). The selection equation for traded patents corresponds to model 2 in Table 5. The outcome equation includes the variable Time to granting. Technology field and grant year dummies have been included in all the models (not reported for space reasons). The robust standard errors are in parenthesis. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.10$.

relationship for the main outcome equation, where the dependent variable, "Time from Application to Transaction", is only observed if the patent is traded. The first-stage selection equation in our framework explains the likelihood of a patent being traded, and is analogous with the probit model presented in Table 4. The post-estimation statistics indicate the appropriateness of the selection model. It should be pointed out that the choice of restricting the sample to traded patents is partially due to the fact that the decision to trade (or not) a patent can be influenced by the presence of significant differences in the rules and regulations, tax breaks and legal procedures in the different countries. However, we expect these factors to play a less important role in the timing of the transaction, on condition a patent had been traded. In fact, we argue that such a time lapse should be driven above all by the presence of uncertainty on the technological and market potential of the contents of the patents.

The results in Table 7 show that the time to transaction is longer for patents with a first priority other than in the US, and it is especially large for patents with a Chinese first priority. Interestingly, the "Technological uncertainty" variable is negatively related to the time to transaction: among the traded patents, those that protect more emerging technologies appear to be traded earlier than those that are not so close to basic explorative research. The time to transaction is also shorter for patents that report a greater number of claims, backward

Table 8
Probit model. Determinants of the likelihood of cross-border patent transactions.

Dependent variable: **from US to non-US**	Model 1
Sample: **US priority patents traded before grant**	
Inventors	0.0214***
	(0.005)
Claims	−0.0023***
	(0.001)
IPC4	0.0070
	(0.020)
PCT dummy	−0.0040
	(0.018)
Technological uncertainty	−0.1305***
	(0.027)
Backward cit. (patent)	−0.0397***
	(0.009)
Forward cit.	−0.0911***
	(0.008)
Technology field dummies	Yes
Grant year dummies	Yes
Observations	34,430
Chi2	1182
Loglike	−14,630
Pseudo R2	0.0420

The dependent variable is the dummy "from US to non-US", a variable equal to 1 if the patent has a US priority and is purchased by a non-US firm, and 0 otherwise. The marginal effect of each independent variable is reported while holding all the variables at their mean value; for dummy variables, dy/dx represents the discrete change from 0 to 1. Technology field and grant year dummies have been included in all the models (not reported for space reasons). The robust standard errors are in parenthesis. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.10$.

citations (both to the patent and not patent literature) and inventors. The patents with a greater number of backward citations mainly cover incremental technologies and show, at the margin, a shorter time to transaction. The time to transaction is instead longer for patents with a higher number of forward citations. Traded inventions are on average of higher quality than non-traded ones. However, among the traded patents, those of superior quality take longer to complete the change in ownership, because sellers are more careful about reaping the maximum benefits from the transaction.

4.4. Cross-border transactions and technological uncertainty

In this section, the aim is to investigate the relevance of asymmetric information in cross-border transactions. In order to do so, we restricted the sample to patents traded before granting[14] that originated in the US and we analyzed, through a probit model,[15] the effect of a number of covariates (including our measure of asymmetric information on the value of the patented technologies, captured by the previously illustrated degree of technological uncertainty) on the likelihood of observing a cross-border transaction (i.e. a non US buyer) versus a domestic transaction (i.e. a US buyer). The results presented in Table 8 reveal that patents that are more science based and which are hence likely to have a higher technological uncertainty (i.e. they have such a number of backward citations to the scientific literature that they fall into the top decile of the distribution for their technological domain), are significantly less likely to be involved in cross-border deals (with a decreasing effect on average equal to −19.24%). It should be recalled that the "Technological Uncertainty" variable is positively associated with the likelihood of a patent being traded (an increase of 8.42%), as reported in the models in Table 5. This joint evidence seems to be

[14] The sample was restricted to patents traded before granting because of the full availability, for this sub-sample, of the country of origin of the buyer.

[15] The model was estimated with the "probit" routine of STATA 13.1

consistent with a context in which firms probably tend to acquire patents on the market for technology that are related to more emerging technological solutions, with an exploratory intent. However, this same characteristic tends to restrain cross border transactions, as a result of the fact that the assessment of the underlying true technical potential of a patented innovation requires substantial resources, and proximity can play a significant role in alleviating such a burden. US priority patents with a greater number of inventors are more likely to be cross-border traded. Instead, US priority patents with a higher number of claims, forward citations and backward citations show a higher probability of being traded domestically.

5. Conclusion

In this paper, we have addressed the question of whether the geographical origin of patents affects the probability of a patent being traded with another entity, the time necessary for such a change in ownership to take place and the possibility of the patent transaction taking place cross-border rather than domestically. We have also singled out the characteristics of patents that might proxy the degree of asymmetric information that could affect the trading of the patents in an international context. We have focused on US granted patents and developed a method to identify the actual patent transactions. The analysis has been confined to transactions that involve bundles of less than 11 patents, in order to limit the misclassification of changes in ownership that are not due to deals on the markets for technology, but rather to outcomes of M & As or within-group transfers.

We have obtained evidence that there has been an increase in the rate of patent transactions in recent years. This trend has proved to be robust to the adoption of estimation methods that account for censoring problems. The obtained results also indicate that the geographical location of buyers and sellers affects the chances of observing an exchange of patents, as does the time lapse between the patent application and transaction date. Coherently with the idea that cross-border transactions might be affected by greater barriers (due to the presence of uncertainty about the technological and market potential of the patent), we have found that US granted patents with a first non-US original applicant have less probability of being traded and show a longer time to transaction than US first priority patents. Such a differential is more pronounced in the case of patents with a Chinese and Japanese priority, but it is also present in the case of patents with a first priority in one of the member countries of the European Patent Convention. This result might be partially driven by factors related to differences in rules and regulations, tax breaks and legal procedures among countries.

We have also found that more science-based patents, which are usually characterized by a greater technological uncertainty, are more likely to be traded, but are significantly less likely to be involved in cross-border deals. This evidence clearly supports previous results on the presence of asymmetric information in the assessment of the underlying technical potential of patents that cover emerging technological solutions. While firms are interested in acquiring these patents on the market for technology, they also have to bear significant costs in evaluating their technological readiness, which in principle can be alleviated when transactions take place in a domestic context.

Overall, the evidence lends support to the arguments that suggest that the uncertainty surrounding the value of patent rights, the underlying technology and the patent trading process might have a hampering effect on international patent trade, especially for those firms that lack financial and technical resources to monitor and evaluate trading opportunities. In fact, asymmetric information on the technological and economic merit of patents could play a prominent role in limiting the expansion of the markets for technology on a global scale.

Our results are coherent with the previous literature that studied information asymmetries on the market for technology and proximity. Other authors found that geographical distance hampers trade on the market for technology (Buenstorf and Geissler, 2012; Alcacer et al., 2007; Drivas and Economidou, 2015), which is instead fostered by trust and personal familiarity (Jensen et al., 2015). In fact, it is more likely that patents are traded more easily among parties in the same country, as being based in the same country is likely correlated to a higher degree of mutual knowledge and trust.

The analysis has some clear limitations due to the characteristics of the available data, which refer to the degree of completeness of the information on patent reassignments. Moreover, the evidence might be affected by specific corporate IP strategies, related to the allocation of IPRs to subsidiaries located in specific countries with the aim of pursuing fiscal benefits or of making it harder for competitors to observe all the assets of a firm's patent portfolio. We also acknowledge that we have not modelled additional factors that could affect cross-border transactions, such as the heterogeneity across countries of the legal aspects of intellectual property or business culture. This represents an interesting question that could be addressed in future research.

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References

Agrawal, A., 2006. Engaging the inventor: exploring licensing strategies for university inventions and the role of latent knowledge. Strateg. Manage. J. 27, 63–79.
Alcacer, J., Cantwell, J., Gittelman, M., 2007. Are licensing markets local? An analysis of the geography of vertical licensing agreements in bio-pharmaceuticals. Harvard Business School Working Paper.
Arora, A., Ceccagnoli, M., 2006. Patent protection, complementary assets, and firms' incentives for technology licensing. Manage. Sci. 52 (2), 293–308.
Arora, A., Fosfuri, A., 2003. Licensing the market for technology. J. Econ. Behav. Organ. 52, 277–295.
Arora, A., Gambardella, A., 2010. Ideas for rent: an overview of markets for technology. Ind. Corporate Change 19 (3), 775–803.
Arora, A., Fosfuri, A., Gambardella, A., 2001. Markets for Technology: The Economics of Innovation and Corporate Strategy. The MIT Press.
Athreye, S., Cantwell, J., 2007. Creating competition? Globalisation and the emergence of new technology producers. Res. Policy 36 (2), 209–226.
Benassi, M., Di Minin, A., 2009. Playing in between: patent brokers in markets for technology. R & D Manage. 39 (1), 68–86.
Bessen, J., Meurer, M.J., 2014. The direct costs from NPE disputes. Cornell Law Rev. 99 (2), 387–424.
Buenstorf, G., Geissler, M., 2012. Not invented here: technology licensing, knowledge transfer and innovation based on public research. J. Evol. Econ. 22, 481–511.
Burhop, C., Wolf, N., 2013. The German market for patents during the "second industrialization", 1884–1913: A gravity approach. Bus. History Rev. 87 (1), 69–93.
Castellani, D., Peri, F., 2013. R & D offshoring and the productivity growth of European regions. Res. Policy 42, 1581–1594.
Caviggioli, F., Ughetto, E., 2013. The drivers to patent transactions: corporate views on the market for patents. R & D Manage. 43 (4), 318–332.
Caviggioli, F., Ughetto, E., 2016. Buyers in the patent auction market: opening the black box of patent acquisitions by non-practicing entities. Technol. Forecasting Social Change 104, 122–132.
Caviggioli, F., Scellato, G., Ughetto, E., 2013. International patent disputes: evidence from oppositions at the European Patent Office. Res. Policy 42 (9), 1634–1646.
Cockburn, I.M., MacGarvie, J.M., Müller, E., 2010. Patent thickets, licensing and innovative performance. Ind. Corporate Change 19 (3), 899–925.
De Rassenfosse, G., Dernis, H., Guellec, D., Picci, L., van Pottelsberghe de la Potterie, B., 2010. Patent Statistics Without the Home Bias: A Corrected Count of Priority Filings Using Patstat. Mimeo.
De Rassenfosse, G., Palangkaraya, A., Webster, E., 2016. Why do patents facilitate trade in technology?: Testing the disclosure and appropriation effects. Res. Policy 45, 1326–1336.
Drivas, K., Economidou, C., 2015. Is geographic nearness important for trading ideas?: Evidence from the US. J. Technol. Transfer 40, 629–662.
Figueroa, N., Serrano, C.J., 2013. Patent Trading Flows of Small and Large Firms. National Bureau of Economic Research (working paper 18982).
Fischer, T., Leidinger, J., 2014. Testing patent value indicators on directly observed patent value: an empirical analysis of Ocean Tomo patent auctions. Res. Policy 43, 519–529.
Fosfuri, A., 2006. The licensing dilemma: understanding the determinants of the rate of technology licensing. Strateg. Manage. J. 27 (12), 1141–1158.

Galasso, A., Schankerman, M., Serrano, C.J., 2013. Trading and enforcing patent rights. RAND J. Econ. 44 (2), 275–312.
Gallini, N.T., Winter, R.A., 1985. Licensing in the theory of innovation. RAND J. Econ. 16 (2), 237–252.
Gambardella, A., Giuri, P., Luzzi, A., 2007. The market for patents in Europe. Res. Policy 36, 1163–1183.
Gans, J.S., Stern, S., 2010. Is there a market for ideas? Ind. Corporate Change 19 (3), 805–837.
Gans, J.S., Hsu, D., Stern, S., 2008. The impact of uncertain intellectual property rights on the market for ideas: evidence from patent grant delays. Manage. Sci. 54, 982–997.
Giuri, P., Mariani, M., Brusoni, S., Crespi, G., Francoz, D., Gambardella, A., Garcia-Fontes, W., Geuna, A., Gonzales, R., Harhoff, D., Christia, H., 2005. Everything you always wanted to know about inventors (but never asked): evidence from the PatVal-EU survey. LEM Papers Series 2005/20. Sant'Anna School of Advanced Studies, Pisa Italy.
Guellec, D., van Pottelsberghe de la Potterie, B., 2000. Applications, grants and the value of patents. Econ. Lett. 69 (1), 109–114.
Guellec, D., van Pottelsberghe de la Potterie, B., 2001. The internationalisation of technology analysed with patent data. Res. Policy 30 (8), 1253–1266.
Harhoff, D., Scherer, F., Vopel, K., 2003. Citations, family size, opposition and the value of patent rights. Res. Policy 32, 1343–1363.
Jensen, P.H., Palangkaraya, A., Webster, E., 2015. Trust and the market for technology. Res. Policy 44 (2), 340–356.
Kulatilaka, N., Lin, L., 2006. Impact of licensing on investment and financing of technology development. Manage. Sci. 52 (12), 1824–1837.
Lamoreaux, N., Sokoloff, K., 2001. Market trade in patents and the rise of a class of specialized inventors in the 19th-century United States. Am. Econ. Rev. 91, 39–44.
Lanjouw, J.O., Schankerman, M., 1997. Characteristics of patent litigation: a window on competition. Rand J. Econ. 32 (1), 129–151.
Lanjouw, J.O., Schankerman, M., 2004. Protecting intellectual property rights: are small firms handicapped? J. Law Econ. 47 (1), 45–74.
Lemley, M.A., Shapiro, C., 2007. Patent holdup and royalty stacking. Texas Law Rev. 85, 1991–2048.
Lerner, J., Seru, A., 2015. The Use and Misuse of Patent Data: Issues for Corporate Finance and Beyond. Mimeo.
Lewin, A.Y., Massini, S., Peeters, C., 2009. Why are companies offshoring innovation?: The emerging global race for talent. J. Int. Bus. Stud. 40, 901–925.
Monk, A.H.B., 2009. The emerging market for intellectual property: drivers, restrainers, and implications. J. Econ. Geogr. 9, 469–491.
Motohashi, K., 2008. Licensing or not licensing? An empirical analysis of the strategic use of patents by Japanese firms. Res. Policy 37 (9), 1548–1555.
Nair, S.S., Mathew, M., Nag, D., 2011. Dynamics between patent latent variables and patent price. Technovation 31 (12), 648–654.
Narula, R., Zanfei, A., 2005. Globalization of innovation: the role of multinational enterprises. In: Fagerberg, J., Mowery, D.C., Nelson, R.R. (Eds.), The Oxford Hand-book of Innovation. University PressOxford, Oxford.
Odasso, C., Ughetto, E., 2011. Patent backed securities in pharmaceuticals: what determines success or failure? R & D Manage. 41 (3), 219–239.
Odasso, C., Scellato, G., Ughetto, E., 2015. Selling patents at auction: an empirical analysis of patent value. Ind. Corporate Change 24 (2), 417–438.
Picci, L., 2010. The internationalization of inventive activity: a gravity model using patent data. Res. Policy 39, 1070–1081.
Reitzig, M., Henkel, J., Heath, C.H., 2007. On sharks, trolls, and their patent prey-unrealistic damage awards and firms' strategies of 'being infringed'. Res. Policy 36 (1), 134–154.
Reitzig, M., 2003. What determines patent value? Insights from the semiconductor industry. Res. Policy 32 (1), 13–26.
Roth, A.E., 2007. The art of designing markets. Harvard Bus. Rev. 85, 118–126.
Roth, A.E., 2008. What have we learned from market design? Hahn Lecture. Econ. J. 118 (March), 285–310.
Serrano, C.J., 2010. The dynamics of the transfer and renewal of patents. RAND J. Econ. 41 (4), 686–708.
Serrano, C.J., 2013. Estimating the Gains from Trade in the Market for Patent Rights. (Unpublished manuscript).
Sneed, K.A., Johnson, D.K.N., 2008. Selling ideas: the determinants of patent value in an auction environment. R & D Manage. 39 (1), 87–94.
Spulber, D., 2008. Innovation and international trade in technology. J. Econ. Theory 138, 1–20.
Teece, D.J., 1986. Profiting from technological innovation: implications for integration, collaboration, licensing and public policy. Res. Policy 15, 285–305.
Van Looy, B., Vereyen, C., & Schmoch, U. (2014). Patent Statistics: Concordance ipc V8-nace, 2. Eurostat.
van Zeebroeck, N., van Pottelsberghe de la Potterie, B., 2011. The vulnerability of patent value determinants. Econ. Innov. New Technol. 20 (3), 283–308.