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Drivas, Kyriakos and Economidou, Claire

Department of Economics, University of Piraeus, Piraeus 185 34,
Greece

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Is Geographic Nearness Important for Trading Ideas? Evidence from the US.[☆]

Kyriakos Drivas^{a,*}, Claire Economidou^a

^a*Department of Economics, University of Piraeus, Piraeus 185 34, Greece*

Abstract

This paper studies the relative geographic scope of two different channels of knowledge flows, a market channel where knowledge diffuses via patent transactions and a non-market channel where knowledge spillovers operate via patent citations. While there is significant work on informal non-market channels of knowledge diffusion, formal market channels of knowledge transfer are less studied, primarily due to the lack of comprehensive data. Using a newly compiled dataset by the Office of the Chief Economist at the United States Patent and Trademark Office of transactions of US issued patents, we are able to provide novel insights on the spread of patent transaction flows across the states of the US. Our findings support that geographic proximity, in terms of distance and border, matters for the spread of knowledge for both channels; however, it is more essential to the operation of market based (patent trades) than to the operation of non-market based (citations) flows. Although both flows are highly localized, the geographic scope of knowledge flows based on citations is larger than that of traded patents. Intra-sectoral flows are also found to be very localized with Mechanical sector to exhibit the most geographically confined knowledge flows, while flows from information technology sectors, i.e., Electronics and Computers, are the most far reached compared to the knowledge flows from the rest of the sectors, both in the US and abroad. Finally, there is no nuance evidence that the importance of distance has declined over time, either at state or national level for both types of flows.

Keywords: patent transactions, citations, knowledge flows, localization, distance
JEL: F10, F23, O33

1. Introduction

Generation of new technological knowledge lies at the heart of economic growth (Romer, 1986; Lucas, 1988). Technological inventions have become the most important source of growth, replacing land, energy, and raw materials.¹ Producing new knowledge, however, is not cheap and highly concentrated (Audretsch and Feldman, 1996). One way to avoid replicating others' ideas and improve the allocation of technology in an economy is by generating tradable intellectual property rights, for example, patents. Specifically, the

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*Corresponding author.

Email addresses: dribask@unipi.gr (Kyriakos Drivas), economidou@unipi.gr (Claire Economidou)

¹During the last two decades, the value of patents and other intellectual property assets has surged to become a large part of the wealth portfolio of firms today. In the early 1980's intangible assets represented 38% of the portfolios of U.S. firms, while in the mid 1990's and 2000's this share rose to 70% (WIPO, 2004). "The economic product of the United States", as Alan Greenspan stated, has become "predominantly conceptual" (Stanford Report, 2004). Intellectual property forms part of those conceptual assets.

market of patents provides incentives to develop innovations (Spulber, 2008) - the inventor can simply sell the patent to a specialized producer and shifts his efforts to a new invention - and reinforces the value of current technology. For example, companies, such as Intel, spend considerable resources explicitly encouraging the external development of complementary technology (Gawer and Cusumano, 2002). In addition to their contribution in increasing the rate of innovation, patent transactions improve the geographic distribution of technology. As knowledge production is concentrated in space, the market of patents facilitates the stretch of a patented idea in space, as potential distant buyers may, too, purchase the innovation.

Moreover, patent transactions act as a channel of acquiring technological knowledge. The idea that patents promote diffusion and creation of technology is not new and dates back to Arrow (1962). Transactions involving technology packages (patents, patent licensing, and other intellectual property and know-how) can entail knowledge exchange between transacted agents. In particular, buying a patent, is not just buying a legal piece of paper. Businesses buy patents to use the technology covered by the patent, which could be vital for their own line of knowledge or goods production. The willingness-to-pay of potential buyer depends on the technological knowledge contained in the patent (Anton and Yao, 1994). In using a patent, sometimes the buyer could develop connections with the seller in order to implement the patented technology. Such contacts could also involve transferring the necessary 'how-to' knowledge to the firm, which buys the patent. Consequently, technological learning could be inferred from patent transactions.²

An important question, in this respect, is whether geographic factors shape the trade of patents and, therefore, affect the allocation of technology across regions and accompanied technological flows. In a globalized world, ideas generated in one place can travel to another very distant one, at an unprecedented rate, via the Internet, phones and other means of communications and boundaries may play little role. Counterarguments, however, suggest that geographic nearness still plays an important role and strongly influences the diffusion of knowledge. Distance may still matter if face-to-face interactions are important, even sometimes in high-tech sectors as knowledge is tacit and hard to codify. Further, more globalization relates to more industry specialization and, therefore, less to learn from one another.

This paper aims to examine whether geographic nearness, state border and distance, shape the trade of patented ideas and, consequently, knowledge flows exemplified by this formal market-based channel for the US over the period 1995-2010. Using detailed and recently developed data on patent reassignments of US-based entities, we explore whether the trade of 'weightless' ideas is confined by geographic factors even within the same country and whether the importance of geography has changed over time due to technological developments.

In general, the literature has documented the localization of market transactions and potential knowledge diffusion generated. In particular, the trade-growth literature infers learning by analyzing trade flows (Coe and Helpman, 1995; Keller, 2002) between industries and countries. According to this literature, importing a foreign intermediate good allows a recipient country to learn from the R&D-, or 'technology'-content embodied in the traded good and merchandise trade acts as an important conduit of market-based knowledge flows across industries and countries. A separate strand of literature, documents evidence of knowledge flows via the mobility of highly skilled personnel, the inventors of patents (Marx et al., 2009). Embodied knowledge in inventors can be spread out via face-to-face interaction between talented individuals (Arrow, 1962). These two channels of knowledge flows generated either via the trade of goods and mobility of innovators involve movements of goods and people, respectively. Consequently, geography could still pertain a nuance role and this is indeed what both strands document. Despite the significant decrease in transportation costs and development of communication technology, distance has not decayed in importance (Disdier and Head, 2008).

However, knowledge flows can be also generated via non-market mechanisms. Undoubtedly, one of the most important contributions in the past twenty years in measuring knowledge spillovers is the work of Jaffe et al. (1993), which introduces patent citations as a metric for knowledge spillovers. Since then, studies have shown that geographic proximity significantly affects both intra-national and international

²A recent study by Serrano (2011) shows that the transfer of patents has become an important source of adopting technology for US firms. The study develops and estimates models of costly technology transfer and renewal in the market for innovation and quantifies possible gains from trading patents as well as costs of adopting technology in the market for patents.

knowledge spillovers (Thompson, 2006; Aldieri, 2011) and such knowledge flows increase innovation output of nearby regions (Peri, 2005). With respect to the significance of geography over time in knowledge diffusion, evidence from the patent-citation literature is rather mixed.³ For instance, Thompson (2006) finds that intra-national knowledge flows in the US have become less localized, while international knowledge flows have remained constant. The studies of Griffith et al. (2011) and Aldieri (2011), on the other hand, provide support that there is a fall in the national home bias for patent citations; nonetheless, the overall home bias effect is still significant in comparison with the decrease observed in recent years.

Despite the importance of patents in economic growth and welfare, there is scant evidence so far on the impact of geography on patent trades and potential formal knowledge flows generated, primarily due to lack of comprehensive data. To our knowledge, there are two studies that undertake such investigation. A recently published study by Burhop and Wolf (2013) documents historical evidence on geographic effects of patent transactions to also infer knowledge diffusion across German regions during 1884-1913. An investigation of patent licenses, as opposed to patent transfers, as a potential channel of knowledge flows, and whether geography shapes the latter, is performed by Mowery and Ziedonis (2001). The authors find that formal knowledge flows, operating by academic licensing, are more bounded by geographic distance compared to informal flows exemplified by patent citations. However, as the authors state, their sample is small, consisting only of four US universities, and focuses only on academic patents.

This paper contributes to the aforementioned emerging literature by adding novel insights on how geography shapes the trade of patents and formal knowledge flows generated by this type of trade. The empirical investigation of the reach of traded patented ideas, both at aggregate and sectoral level, in the US - one of the most innovative countries in the world - consists the first attempt in the literature. To get a sense of our estimates, we also examine the geographic reach of patent citation flows, and contrast the findings.

At the outset of our paper we would like to note that patent trade flows, as a measure of knowledge flows, is susceptible to criticisms also applied to other measures of knowledge flows namely patent citations, trade of goods, and inventors' mobility as to whether they capture 'actual' knowledge flows or noise, too.⁴ Firms can also buy patents for defensive reasons - to help defend the patents the company already owns by acquiring similar technology. Consequently, patent trades could proxy more things than knowledge flows between buyer and seller. To capture actual knowledge transmitted between involved agents, one could, for instance, employ the citations a patent receives from the perspective buyer before the transaction, i.e., firms that acquire a patent could also previously cite the patent. The size and nature (e.g., start-up firms, established) of a firm could also be relevant, as small-sized firms tend to buy patents for technology purposes, while large ones for strategic reasons. Unfolding, however, the reason behind the patent transaction, i.e., whether it is pure strategy or knowledge acquisition, has not been easy thus far, due to data unavailability and still unmatched databases. The use of patent licenses, instead of patent trades, could provide an alternative more appropriate proxy of knowledge exchange due to the frequency of contacts between the patent licensor and licensee. Patent licensing data are, however, proprietary and constructed via surveys for a limited number of firms or US universities (Mowery and Ziedonis, 2001). Finally, patent trades, as a metric of knowledge flows, capture a sub-set of knowledge diffusion - the patented knowledge - ignoring, for instance, knowledge, which is not patentable.

Our empirical analysis is developed around two key questions: First, to what extent do we observe similar localization in patent transfers as in the well-documented case of patent citations? Second, does the significance of geographic factors for patent transactions change over time?

Our empirical analysis proceeds as follows: We estimate a gravity-like equation in order to assess the role of nearness on patent transactions. To elaborate more on our findings we provide evidence from state level and sector level analysis, performing a number of robustness tests. To examine whether border and distance have declined or still persisting over time, the econometric specifications account for an early time period (1995-2002) and a recent time period (2003-2010) and examine the differences. Lastly, to get a sense

³For an excellent and up-to-date review of knowledge flows and geography see Autant-Bernard et al. (2013).

⁴See for a discussion the study of Criscuolo and Verspagen (2008).

of the size of our patent trade estimates, we also examine time and geographic effects on citation flows and contrast the evidence.

Our results clearly support strong localization of patent transaction flows as states tend to involve more in exchanging patents and citations within their borders than with other states or countries, but there is no nuance evidence, however, for higher significance of nearness over time. Citation flows also appear to be less geographically confined than patent transaction flows and eventually knowledge flows based on citations exchange are more far stretched in space than their counterparts based on patent trade. This is quite apparent, especially, when it comes to very large distances in the US, for instance, exchange of patents or citations between East and West Coast. While distance is a strong hurdle for both flows, its effect is more dramatic on patent transactions. Sector level analysis of patent transaction and citation flows confirms state level findings. Intra-sectoral flows are also found to be very localized with Mechanical sector to exhibit the most geographically confined knowledge flows, while flows in information technology sectors, i.e., Electronics and Computers, are the most far reached compared to the knowledge flows from the rest of the sectors, both in the US and abroad. We also explore the role of agglomeration in shaping the geographic localization of patent trade. Our results do not support a strong evidence between agglomeration and trade of ideas across space and time.

The implications of our findings for the growth literature are potentially relevant. Although theoretical studies (Rivera-Batiz and Romer, 1991) emphasize the important consequences of disembodied knowledge flows over knowledge embodied, there has been little effort, on the empirical side, to explore all mechanisms of disembodied knowledge diffusion. Along with other important studies, this paper makes an effort towards analyzing disembodied knowledge diffusion via the channel of patent trades, complementing, thus, important contributions in the field of disembodied knowledge diffusion.

The remainder of the paper is laid out as follows. Section 2 introduces the framework of our analysis and discusses the data. Section 3 presents the results. Section 4 summarizes our findings and concludes.

2. Methodology

2.1. Model Specification

We use a simple gravity-like equation, proposed and used in the trade literature (Krugman, 1991) and economics of innovation and spillover literature (Peri, 2005), to model bilateral patent transaction flows as a function of geographic and time factors:

$$\begin{aligned} \tau_{ijt} = & \beta_0 + \beta_1 State\ Border_{ij} + \beta_2 Nearby\ States\ [500\ miles]_{ij} + \\ & \beta_3 Distance\ [500 - 1,500\ miles]_{ij} + \beta_4 Distance\ [> 1500\ miles]_{ij} + \\ & \beta_5 OutOfCountry_{ir} + \beta_6 Dummy_{ijt} + \beta_7 Z_{ijt} + \epsilon_{ij} \end{aligned} \quad (1)$$

where τ_{ijt} is patent transaction flows between two states i (destination) and state j (origin); *State Border* takes the value of 1 for flows exchanged between states i and j that share a common border and 0 otherwise; *Nearby States [500 miles]* takes the value of 1 for flows exchanged between states that do not share a common border and their geographical centers are located within a distance of 500 miles, and 0 otherwise; *Distance [500 – 1,500 miles]* is a distance class of 500 to 1,500 miles and takes the value of 1 for flows exchanged between states i and j that are located within 500 to 1,500 miles, and 0 otherwise; *Distance [> 1,500 miles]* is a distance class of larger than 1,500 miles and takes the value of 1 for flows exchanged between states i and j that are located in a distance larger than 1,500 miles and 0 otherwise; *OutOfCountry* is a dummy that takes the value of 1 if states involve in international patent trade and 0 if they do not; *Dummy* is a time dummy variable which takes the value of 0 if a patent is traded in the period 1995-2002 and 1 if it is traded in the period 2003-2010; the vector Z contains time and distance interaction terms, and ϵ is an iid error term.

The coefficients β_1 till β_5 provide a characterization of how pure geographic factors shape the flows of patent trade. By model construction, each geographic coefficient captures the difference between knowledge flows diffused in geographic space to knowledge flows within a state. Consequently, the coefficient

of the first dummy, *State Border*, captures how much patent transaction and possible knowledge exchange takes place between states that share a common state border compared to in-state level of exchange. Irrespective of the border effect, the second dummy, *Nearby States [500 miles]*, captures the differences in patent trade exchanged between states located in a distance of 500 miles compared to in-state transactions. The coefficients of the (rest of the) distance dummies, examine whether states that have been located in various distance classes exhibit different patent trade interactions in comparison to in-state level of interactions. We opted for this distance taxonomy because the longest distance in miles between two neighboring states is approximately 500 (517,705 miles to be precise), which is the distance between the centers of Colorado and Oklahoma. Then, we proceed with batches of 1,000 miles till the distance between East and West Coast is exhausted. In addition, the coefficient of *OutOfCountry* allows to explore international aspects of patent trade transactions. It captures the difference in patent trade of state i that has with the rest of the world (denoted as 'region' r) compared to in-state transactions. One would expect that larger geographic distance would reduce exchange of patents and consequently knowledge flows across the states due to the presence of spatial transaction and other information costs, signaling that knowledge flows are bounded in space and characterized by spatial declining effect. Strong localization effects occur when almost all patent trade activity takes place in-state rather than across states (or abroad).⁵

Further, the time dummy, *Dummy* captures whether more recent trade is more (or less) localized than earlier one. If the role of nearness declines over time, then one would expect for β_6 to be negative and statistically significant. Lastly, to explore time patterns of nearness and international patent transactions, we also include time-distance interaction terms, in the vector Z . If their coefficients are negative and statistically significant, then this would be an indication of possibly higher significance of distance over time, i.e., strong "still persisting" distance effect.

2.2. Estimation Technique

Patents and citations are 'count data' - and some states record zero information on either patents or citations. To handle this type of data, we use a generalization of the Poisson model, known as negative binomial estimator, which is frequently used in similar to ours contexts (Peri, 2005; Perkins and Neumayer, 2011; Furman and Stern, 2011) and does not rely on the restrictive assumption that the conditional means to be equal the conditional variances, as Poisson does.⁶ Another advantage of using negative binomial its ability to accommodate 'zero' outcomes of the dependent variable.

To assess the geographic and time effects on patent transaction flows across states of the US, we estimate equation (1) for different sub-samples and alternative definitions of patent transaction flows, i.e., τ_{ijt} in equation (1) could be either all flows, or first flow or last flow of patent transactions or even citation flows in order to compare our evidence of patent transactions with that of patent-citation literature.

2.3. Data Description and Analysis

Our empirical analysis is based on 50 states of the US for the period 1995 to 2010.

The primary source of patent data is a recently compiled dataset by the office of the chief economist of the United States Patent and Trademark Office (USPTO), kindly provided to us, referred as Patent Assignment Dataset, which contains assignments (transactions) of US issued patents between entities registered at the USPTO.⁷ A typical assignment is characterized by a unique identifier (i.e., reel frame), the names of the buyer (i.e., assignee), the seller (i.e., assignor), the date that the transaction agreement was signed (execution date), and the patent numbers or patent applications that are traded per assignment.⁸ In constructing

⁵The localization of knowledge flows has been considerably tested in the spillover literature, which almost unanimously documents that physical distance does matter and spillovers are constrained geographically (Jaffe et al., 1993; Peri, 2005; Thompson, 2006; Alcacer and Gittelman, 2006; Belenzon and Schankerman, 2011).

⁶The ordinary least squares (OLS) estimation, in such models, yields inconsistent estimates (Santos Silva and Tenreyro, 2006, 2010). For a formal development of negative binomial model, see Hausman et al. (1986).

⁷In the US, when entities transfer US issued patents to other entities, they disclose such transactions to the USPTO. The latter are called assignments.

⁸There is also a field in the assignment data in which entities can disclose the justification for the transfer. However, the justification, in most cases, is a generic one (i.e. assignment of assignor's interest). Therefore, it is really difficult to extract information from that field.

our patent dataset, we faced two main challenges when employing assignment data. The first relates to the fact that entities are not required to disclose transactions to the USPTO. However, for legal and perhaps accounting reasons, they have incentives to do so.⁹ A challenge associated with using assignment data is that it is still likely that a number of transactions have not been disclosed to the USPTO due to negligence or to strategic behavior. In any case, we do not expect this to be systematic for aggregated transactions across geographic areas. An additional challenge is associated with excluding 'routine' transactions. In the US, only an individual can file for a patent application. Subsequently, this individual may re-assign the patent application (or patent) to her firm or institution where she is employed. These transactions are also included to the dataset. Thus, the challenge here is to isolate the economically meaningful re-assignments and discard otherwise. Taking these two challenges into consideration, we end up having 96,478 patents issued between 1995 and 2010 that have been traded from US located entities and are associated with 102,876 transactions for which we have location information for both the assignor and assignee.

There is a many-to-many relationship between patents and transactions. That is, transactions may contain more than one patents and a patent may be transacted more than once. To construct the flows of patents, we aggregate the number of patents that have been traded from entities located in origin state to entities in destination state for any year. For patents, which are traded more than once, each transaction is registered as a new transaction and, therefore, counted accordingly. Therefore for patents traded more than once, and for robustness purposes, we construct two alternative measures of patent flows. The first is called, 'first flow' and considers, for each patent, only its first assignment, ignoring the rest of its transactions. The second measure is called 'last flow' and for each patent excludes all the intermediate transactions and records only the assignment between the first and last entity. For example, for a certain patent which is sold from California to New York state and then from New York state to Texas, the measure 'all flows' registers both transactions, while the other two measures register only one transaction: 'first flow' registers the transaction between California to New York state, and 'last flow' registers the one between California to Texas.

Citations of traded patents data originate from the work of Lai et al. (2011), which is publicly available. The database contains citations of all US issued patents up until 2010. We construct bilateral citation flows between states for the period 1995-2010 by considering citations made from 1995 to 2010 to patents issued between 1995-2010. To construct bilateral citation flows across states, we consider the location of the lead inventor (written on the patent document wrapper) for all (citing and cited) patents.

Finally, the geographic distance (in miles) between two states is the distance between each state's geographic center calculated as the crow flies. This information is obtained from Google Maps.¹⁰ Information on a state's R&D expenditure is extracted from the National Science Foundation *Science and Engineering State Profiles*.

Table 1 below provides the descriptive statistics of the variables included in our model.

⁹For instance, in a potential litigation the courts will need to know clearly which firm or organization holds the intellectual property in question.

¹⁰See <http://www.freemaptools.com>.

Table 1: Summary Statistics

variables	Observations	Mean	St. Dev.	Min	Max
<i>Patent Trade All Flows</i>	42432	3.86	37.02	0	2699
<i>Patent Trade First Flow</i>	42432	3.22	31.38	0	2343
<i>Patent Trade Last Flow</i>	42432	3.22	30.36	0	2259
<i>Citation Flows</i>	42432	46.60	374.14	0	22727
<i>State Border</i>	2652	0.08	0.28	0	1
<i>Nearby States [< 500 miles]</i>	2652	0.11	0.32	0	1
<i>Distance [500 – 1,500 miles]</i>	2652	0.50	0.50	0	1
<i>Distance [$> 1,500$ miles]</i>	2652	0.26	0.44	0	1

Note: *Patent Trade All Flows*, *Patent Trade First Flow*, *Patent Trade Last Flow*, and *Citation Flows*, are occurrences; *State Border* is dummy (1 if states for common border, 0 otherwise); Distance classes: *Nearby States [< 500 miles]*, *Distance [500 – 1,500 miles]*, and *Distance [$> 1,500$ miles]* are dummies (1 if states locate with the class, 0 otherwise).

According to Table 1, for the period under investigation, states, on average, trade about 3 to 4 patents per year and exchange about 47 citations per year. On average, each state pair is 8% likely to be neighboring with each other. Furthermore, 11% of all possible pairs of states are closer than 500 miles and do not share common state border, 50% are located in a distance of 500 to 1,500 miles, and 26% in a distance of larger than 1,500 miles.

Table A.1 in the Appendix reports summary statistics per state. States like California (CA), New York (NY), Illinois (IL), Massachusetts (MA), Michigan (MI), and Texas (TX) are top patent producers, traders and citers of patents. These states also enjoy high R&D spending. In the opposite side of the spectrum are the states of Alaska (AK), Hawaii (HI), the Dakotas (SD and ND) and Wyoming (WY). Overall, summary statistics per state reveal a large variety of patterns.

Below, Figure 1 shows the production of innovation in the US. As it is apparent, intense innovation activity is concentrated in few states in the US. More than 60% of production of patents takes place in five states, California (CA) and New York (NY), which stand out among the top producers, followed by Texas (TX), Illinois (IL), and New Jersey (NJ). The least involved states in producing innovation are Alaska (AK), Hawaii (HI), North Dakota (ND), South Dakota (SD), and Wyoming (WY). Moreover, states which are patent production leaders are also top performers in patent citations and patent trades.

Figure 1: Patent Production per State

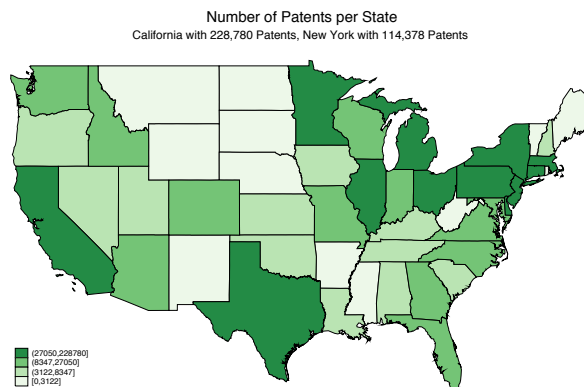
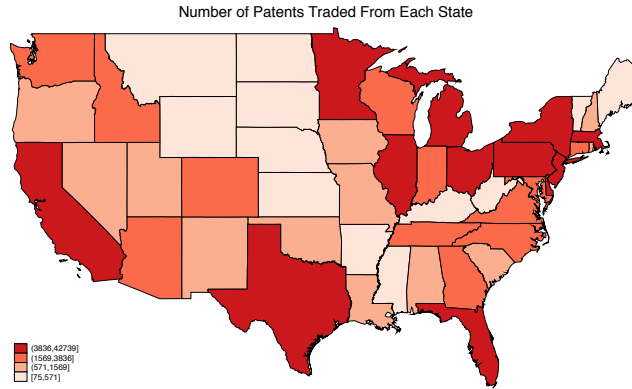


Figure 2 shows the distribution of patent transactions across states in the US.

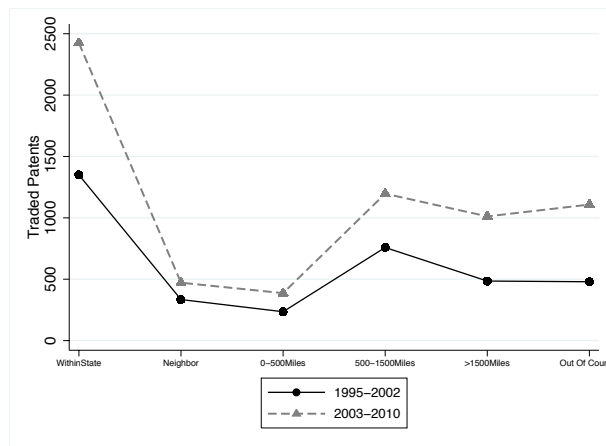
Figure 2: Patents Traded per State



As one observes, states that produce large volumes of patents (see Figure 1, above) are the ones greatly involved in patent transactions.

Lastly, Figure 3 visualizes our data and depicts the decay of patent transaction flows moving out of a state, out of the nearby neighbor, and out by steps of 1,000 miles. Bold line represents early period flows, 1995-2002 and light, dashed line late period flows, 2003-2010.

Figure 3: Decay of Patent Transaction Flows Due to Geographical Barriers



The evidence from the figure above confirms the significance of nearness in shaping patent transaction flows. The decay effect is apparent: state border and distance restricts the trade of patents. There is a sharp decrease of flows and only a small share crosses 500 miles. As the distance becomes large enough - more than 1,500 miles - they pick up again due to the intensity of ideas exchange between East and West (California). Finally, flows for distance between 500 and 1,500 miles show a pick, which is probably due to flow exchange of a state with with Illinois, Texas, and Michigan. Prior to 2002, flows (bold line) are smaller in volume compared to ex post 2002 flows (dashed line). Neighboring patent trade is roughly similar between the two time periods, implying that in-state patent trade has increased in recent years.

3. Empirical Results

This section presents our results. We first examine whether geography shapes patent transactions across the states of US. Then, we proceed by providing more disaggregated evidence from six technological sectors. We further relate to past studies by bringing evidence on the effect of geographic nearness on citation flows, which is the most investigated type of knowledge flow in the literature. Finally, we derive implications on a possible relationship between agglomeration and geographic localization of trading patents across the US.

3.1. How Important is Geography for Patent Transactions across States?

We investigate patent transaction flows originating from an average state and then flows originating from the most and less innovating states of the US. Accordingly, we present our findings.

Patent Transactions of Average State

Table 2 depicts the results. All columns report negative binomial estimates from equation (1). Column (i) is the basic specification and shows estimates for all traded patent flows (*All Flows*). For robustness purposes, we also report estimates based on first traded patent flow (*First Flows*) and last traded patent flow (*Last Flows*) in columns (ii) and (iii), respectively. Furthermore, columns (iv), (v), and (vi) report patent flows in accordance with columns (i), (ii), (iii), but for a slightly different sample: we exclude patents issued between 1995 and 2002, but were traded later between 2003 and 2010. Having kept them in the sample, any decay of importance of nearness could be attributed also to such patents which take many years to be transferred, and as they are known for quite long time, they may be transferred further away.¹¹

Recent evidence from the citations literature gives support to this factor, that in addition to a time dimension there might be an aging dimension in which geographic proximity becomes less important (Li, 2009). Heteroscedastic robust standard errors are provided in parentheses.

As Table 2 shows, estimates are similar across alternative definitions of patent transaction flows and samples. Each geographic coefficient in Table 2 captures the difference between knowledge flows diffused in geographic space to in-state knowledge flows, which is our benchmark by model construction. To convert each value to percentage change, one needs to use the exponential formula. We begin our discussion with estimated coefficients of column (i), which is the basic specification.

The coefficient of *State Border* implies that states, which are neighbors and, therefore, share common border, exchange about 93.3% ($= 1 - e^{-2.697}$) less patents to what they would exchange within their borders. In other words, on crossing a state border, transactions of patents diminish to 6.7% ($= e^{-2.697}$) compared to in-state level of transactions. Irrespective of the border, distance also shapes patent transactions. States that are nearby, in the vicinity of 500 miles, but do not share common borders, exchange 96.6% ($= 1 - e^{-3.392}$) less patents than what they would exchange within themselves as the coefficient of *Distance [< 500 miles]* indicates. Put it differently, the volume of transactions when crossing non-adjacent states, diminishes to 3.4% ($= e^{-3.392}$) to its in-state level of transaction. Further, patent transactions between states located in an area between 500 and 1,500 miles decrease by 97.6% ($e^{-3.709}$) compared to what takes place in-state, as the coefficient of *Distance [500 – 1,500 miles]* indicates. In other words, only 2.4% of the patent trade takes place within a distance of 500 to 1,500 miles. An interesting finding, however, emerges when distance between states becomes long enough, specifically bigger than 1,500 miles. Although (long) distance exerts a heavy toll on the volume of patent trade, the reduction of traded patent volume, however, is smaller compared to the previous distance interval. This seemingly controversial finding is due to the 'California effect'. Despite its distance from a typical state, California is an exceptional producer and trader of patents. In sum, geographic factors (border and distance) comprise a serious limitation of patent transactions across the states of the US. The trade of patents and, consequently, generated knowledge based on these transactions, is limited mainly by the state border, which is an important hurdle to out-of-state patent transactions and

¹¹Patents re-assigned before 2002 have a lag between issue date and execution date of 1.41 years, while patents re-assigned after 2002 have a lag of 3.8 years. The difference is statistically significant.

by geographic distance, where significant knowledge reduction takes place already within a district of 500 miles and any further increase of distance has, practically, no additional reduction effect. States trade 60% less patents with other countries than what they would trade within their state borders, as the coefficient of *Out of Country* enters negatively and statistically significant.

Table 2: Geographical Effects of Patent Transaction Flows (average state)

	All Patents ^I			Aged Patents Excluded ^{II}		
	All Flows ^a	First Flow ^b	Last Flow ^c	All Flows ^a	First Flow ^b	Last Flows ^c
	(i)	(ii)	(iii)	(iv)	(v)	(vi)
<i>State Border</i>	-2.697*** (0.169)	-2.661*** (0.176)	-2.556*** (0.166)	-2.684*** (0.169)	-2.609*** (0.173)	-2.507*** (0.163)
<i>Nearby Area</i> [< 500 miles]	-3.392*** (0.135)	-3.375*** (0.136)	-3.319*** (0.134)	-3.384*** (0.134)	-3.314*** (0.133)	-3.253*** (0.130)
<i>Distance</i> [500 – 1,500 miles]	-3.709*** (0.136)	-3.719*** (0.139)	-3.626*** (0.134)	-3.701*** (0.135)	-3.659*** (0.135)	-3.567*** (0.130)
<i>Distance</i> [$> 1,500$ miles]	-3.504*** (0.136)	-3.519*** (0.137)	-3.359*** (0.135)	-3.503*** (0.134)	-3.461*** (0.133)	-3.299*** (0.130)
<i>Out of Country</i>	-0.908*** (0.215)	-0.863*** (0.222)	-0.692*** (0.210)	-0.950*** (0.201)	-0.886*** (0.204)	-0.710*** (0.195)
<i>Dummy</i>	0.634*** (0.189)	0.607*** (0.195)	0.642*** (0.195)	0.0349 (0.202)	0.108 (0.201)	0.152 (0.201)
<i>State Border</i> \times <i>Dummy</i>	-0.303 (0.241)	-0.361 (0.256)	-0.413* (0.249)	-0.345 (0.266)	-0.406 (0.273)	-0.459* (0.265)
<i>NearbyArea</i> [< 500 miles] \times <i>Dummy</i>	-0.137 (0.211)	-0.194 (0.218)	-0.198 (0.217)	-0.211 (0.225)	-0.287 (0.226)	-0.315 (0.223)
<i>Distance</i> [500 – 1,500 miles] \times <i>Dummy</i>	-0.178 (0.209)	-0.236 (0.217)	-0.257 (0.214)	-0.267 (0.223)	-0.329 (0.224)	-0.359 (0.222)
<i>Distance</i> [$> 1,500$ miles] \times <i>Dummy</i>	0.0978 (0.210)	0.0301 (0.219)	-0.0520 (0.217)	0.0385 (0.226)	-0.0221 (0.228)	-0.114 (0.226)
<i>Out ofCountry</i> \times <i>Dummy</i>	0.204 (0.289)	0.165 (0.298)	0.0580 (0.289)	0.296 (0.295)	0.260 (0.299)	0.132 (0.292)
<i>Constant</i>	3.842*** (0.120)	3.702*** (0.120)	3.626*** (0.119)	3.814*** (0.119)	3.629*** (0.117)	3.551*** (0.115)
Observations	42,432	42,432	42,432	42,432	42,661	42,687

All columns report negative binomial estimates and heteroskedastic robust standard errors (in parentheses). All regressions include time dummies and origin and destination state fixed-effects. *State Border* takes the value of 1 for flows exchanged between states i and j which are neighbors (share a common border) and 0 otherwise; *Nearby States* [500 miles] takes the value of 1 for flows exchanged between states that do not share a common border and their geographical centers are located within a distance of 500 miles, and 0 otherwise; *Distance* [500 – 1,500 miles] is a distance class of 500 to 1,500 miles and takes the value of 1 for flows exchanged between states i and j that are located within 500 to 1,500 miles distance class, and 0 otherwise; *Distance* [$> 1,500$ miles] is a distance classes of larger than 1,500 miles and takes the value of 1 for flows exchanged between states i and j that are located in a distance larger than 1,500 miles and 0 otherwise; *Out of Country* is a dummy and takes the value of 1, if a patent is traded between a state in the US and a foreign country, and 0 otherwise; *Dummy* is a time dummy variable which takes the value of 0 if a patent is traded in the period 1995-2002 and 1 if it is traded in the period 2003-2010; The variables *State Border* \times *Dummy*, *NearbyArea* [< 500 miles] \times *Dummy*, *Distance* [500 – 1,500 miles] \times *Dummy*, *Distance* [$> 1,500$ miles] \times *Dummy*, *Out ofCountry* \times *Dummy* are border-, distance-, region-time interaction terms. (***) : significance at 1%, 5%, and 10% level, respectively.

^I : All patent included.

^{II} : Excludes patents granted early in the period (before 2002), but traded later (after 2003).

^a *All Flows* considers for each multiply transacted patent, all its flows, as separate ones.

^b *First Flow* considers, for each transacted patent, only its first assignment, ignoring the rest of its transactions.

^c *Last Flow* considers, for each transacted patent, only its last assignment, ignoring the rest of its transactions.

Next, we turn into examining whether there are any time effects shaping the pattern of patent transac-

tions across the States of the US. As our results show, the coefficient of time dummy, *Dummy*, is positive and statistically significant, indicating that over time, or after 2002 in particular, in-state patent exchange has risen by 88.5% compared to in-state patent trade prior to 2002. This finding does not necessarily translate into increased importance of distance for patent trade over time. As there is an increase, over time, of patent transactions across states in the US, a higher share of this trade takes place in-state. Concerning the time and distance interaction terms, states seem to involve in less patent trade with their neighbors *ex post* 2002 than *ex ante* as, over time, there is an *additional* decrease of patent transactions across states compared to in-state level of transactions.¹² In contrast, there is a noticeable increase of patent trade between very distant states, more than 1,500 miles, compared to before-2002 as it is evident from the coefficient of *Distance* [$> 1,500$ miles] \times *Dummy* mainly due to the California effect and its increased patent production and transaction over time. Lastly, over time, there is no concrete evidence on the pattern of patent transaction localization at national this time level, as the coefficient of the interaction term, *Out of Country* \times *Dummy*, is not statistical significant. Based on the evidence provided by the interactions terms we cannot argue over greater or lower importance of distance over time as their coefficients appear to be statistically insignificant.

To sharp the robustness of our results, we have performed several checks. We first consider alternative definitions of patent transaction flows. More precisely, we estimate the same specification as in column (i), but with different dependent variables: *First Flow* in column (ii) and *Last Flow* in column (iii). Estimates in both columns are in the vicinity of those reported in column (i). Further robustness for aging effects, replicates the analysis in columns (i) to (iii), but excluding patents granted early but transacted after 2002. The estimated effects, reported in columns (iv) to (vi), remain virtually the same.¹³

Concluding, geographic nearness in terms of border and distance, exerts a strong influence on patent transactions across states of the US. The general and well-documented finding of geographic restriction of flows reported in the literature, is corroborated by our results. In particular, local bias on the state level appears to be quite sturdy in all alternative definitions of patent transactions. The very significant impact of distance on traded patents across states of the US is at first sight quite surprising and puzzling: unlike goods, patented ideas are weightless, and distance cannot just proxy only transportation costs.¹⁴ Further, state border appears to confine trade of ideas as it does with trade of goods, and certainly this effect cannot be attributed to higher transportation costs when a traded patent crosses a state border. Instead, distance and border could be seen as informational barriers, and therefore can serve as proxies for all types of informational frictions: agents within a state tend to know much more about each other and each other's business and technologies, either because of direct interactions between their citizens or because of better media coverage. In consequence, distance and border act as barriers to interactions, various micro-cultural affinities, and networking of economic agents (Saxenian, 1994). It appears that trade of patents requires intensive information to take place and this is reflected on the size of both border and distance coefficients.

The localization robustness of weightless ideas documented in our study, matches also findings from quite different lines of research. For example, studies in the financial trade literature, using 'gravity-like' models have investigated whether geographic distance imposes a hurdle on financial asset transactions, which are weightless compared to goods. In fact, Portes et al. (2001) and Portes and Rey (2005) examine the determinants of cross-border assets (corporate bonds equities and treasury bonds) and show that gravity model explains financial asset transactions at least as well as goods trade transactions and further document a very strong negative effect of distance on all asset flows.

¹²One should be careful when reads the effect of the coefficients of the interaction terms of nonlinear models, like ours. For more detailed discussion, see Ai and Norton (2003).

¹³A battery of additional robustness tests are also performed, but not presented here. For instance, we dropped from our sample the very distant states with the most zeros, Alaska and Hawaii. The exclusion of Alaska and Hawaii barely changes the results. Then, we excluded California, which in terms of patent performance could act as an outlier. Results, available upon request, mildly change, but overall conclusions drawn hold. A notable difference is that, the (long) distance effect, due to California, i.e., more patent transaction flows between distant states, disappears. Overall, results do not change in any significant way across different specifications and sub-samples.

¹⁴A large volume of literature has documented the negative impact of geographic distance and borders on the flows of physical trade. See Wolf (2000) for a discussion on the impact of state border and distance on US trade of goods flows.

Our estimates confirm the picture emerged in Figure 3 as they capture this significant and sharp drop when flows cross state border and distance of 500 miles and then their path remains pretty much stable with some spikes.

Patent Transactions of Top and Least Innovator States

In this section, as a further robustness check, we examine whether the geographic scope of patent transaction flows from top innovator states is wider than the average state flows (Peri, 2005).

To explore this aspect, we consider knowledge flows originating *only* from the top innovator states when estimating equation (1).

We select the top innovators to be states with the highest R&D spending. The states of California (CA), Massachusetts (MA), Michigan (MI), New Jersey (NJ), and New York, (NY), Texas (TX), Illinois (IL), Pennsylvania (PA), Maryland (MD), Washington (WA), and Ohio (OH) are among the top 10 states in R&D spending and account for about 70% of the total US R&D activity in our sample. Therefore, they may act as innovation leaders.

Table 3 depicts the results. Columns in Table 3 are in accordance with those of Table 2. The only difference is that the most innovative states, the top innovators, are the only source, j , of the patent transaction flows in equation (1). Again, one should read the estimated coefficient in the same way as explained in the previous section.

Estimates show that top leaders' patent transaction flows are about equally geographically localized, both in terms of state border and distance, as those of the average state flows. Consequently, our results do not confirm the broader reach of leaders' traded patent flows and potential generated knowledge from the leaders via patent exchange. The analysis of leaders' flows confirms that independent of the origin of a state, i.e., whether the state is an average or innovator state, the spatial reach of patent exchange, and consequent knowledge flows generated, is strongly geographically confined.

Table 3: Geographical Effects of Patent Transaction Flows in the US (top innovators)

	<i>All Patents</i> ^I			<i>Aged Patents Excluded</i> ^{II}		
	<i>All Flows</i> ^a	<i>First Flow</i> ^b	<i>Last Flow</i> ^c	<i>All Flows</i> ^a	<i>First Flow</i> ^b	<i>Last Flows</i> ^c
	(i)	(ii)	(iii)	(iv)	(v)	(vi)
<i>State Border</i>	-2.797*** (0.228)	-2.750*** (0.235)	-2.632*** (0.219)	-2.782*** (0.227)	-2.670*** (0.232)	-2.573*** (0.217)
<i>Nearby Area</i> [< 500 miles]	-3.952*** (0.180)	-3.947*** (0.180)	-3.836*** (0.176)	-3.947*** (0.178)	-3.856*** (0.176)	-3.745*** (0.173)
<i>Distance</i> [500 – 1,500 miles]	-4.019*** (0.182)	-4.057*** (0.181)	-3.965*** (0.171)	-4.012*** (0.181)	-3.966*** (0.178)	-3.877*** (0.168)
<i>Distance</i> [$> 1,500$ miles]	-3.604*** (0.175)	-3.615*** (0.175)	-3.436*** (0.171)	-3.606*** (0.173)	-3.526*** (0.170)	-3.345*** (0.167)
<i>Out of Country</i>	-0.896*** (0.279)	-0.854*** (0.287)	-0.672** (0.270)	-0.952*** (0.260)	-0.871*** (0.265)	-0.687*** (0.252)
<i>Dummy</i>	0.735*** (0.240)	0.705*** (0.242)	0.760*** (0.241)	0.111 (0.256)	0.253 (0.252)	0.315 (0.251)
<i>State Border</i> \times <i>Dummy</i>	-0.397 (0.318)	-0.434 (0.330)	-0.479 (0.317)	-0.333 (0.349)	-0.452 (0.354)	-0.477 (0.339)
<i>Nearby Area</i> [< 500 miles] \times <i>Dummy</i>	-0.159 (0.274)	-0.172 (0.281)	-0.245 (0.277)	-0.242 (0.295)	-0.341 (0.293)	-0.433 (0.287)
<i>Distance</i> [500 – 1,500 miles] \times <i>Dummy</i>	-0.215 (0.274)	-0.264 (0.280)	-0.289 (0.273)	-0.234 (0.298)	-0.349 (0.296)	-0.366 (0.289)
<i>Distance</i> [$> 1,500$ miles] \times <i>Dummy</i>	0.00579 (0.264)	-0.0668 (0.268)	-0.168 (0.265)	-0.0467 (0.282)	-0.174 (0.279)	-0.287 (0.276)
<i>Out of Country</i> \times <i>Dummy</i>	0.103 (0.363)	0.0685 (0.369)	-0.0553 (0.356)	0.244 (0.370)	0.169 (0.372)	0.0303 (0.362)
<i>Constant</i>	5.115*** (0.157)	4.983*** (0.156)	4.893*** (0.153)	5.088*** (0.156)	4.867*** (0.152)	4.774*** (0.151)
Observations	8,320	8,320	8,320	8,320	8,425	8,436

All columns report negative binomial estimates and heterokcedastic robust standard errors (in parentheses). All regressions include time dummies and origin and destination state fixed-effects. *State Border* takes the value of 1 for flows exchanged between states i and j which are neighbors (share a common border) and 0 otherwise; *Nearby States* [500 miles] takes the value of 1 for flows exchanged between states that do not share a common border and their geographical centers are located within a distance of 500 miles, and 0 otherwise; *Distance* [500 – 1,500 miles] is a distance class of 500 to 1,500 miles and takes the value of 1 for flows exchanged between states i and j that are located within 500 to 1,500 miles distance class, and 0 otherwise; *Distance* [$> 1,500$ miles] is a distance classes of larger than 1,500 miles and takes the value of 1 for flows exchanged between states i and j that are located in a distance larger than 1,500 miles and 0 otherwise; *Out of Country* is a dummy and takes the value of 1, if a patent is traded between a state in the US and a foreign country, and 0 otherwise; *Dummy* is a time dummy variable which takes the value of 0 if a patent is traded in the period 1995-2002 and 1 if it is traded in the period 2003-2010; The variables *State Border* \times *Dummy*, *Nearby Area* [< 500 miles] \times *Dummy*, *Distance* [500 – 1,500 miles] \times *Dummy*, *Distance* [$> 1,500$ miles] \times *Dummy*, *Out of Country* \times *Dummy* are border-, distance-, region-time interaction terms. (**): significance at 1%, 5%, and 10% level, respectively. Top innovator states: California (CA), Massachusetts (MA), Michigan (MI), New Jersey (NJ), and New York, (NY), Texas (TX), Illinois (IL), Pennsylvania (PA), Maryland (MD), Washington (WA), and Ohio (OH).

^I: All patent included.

^{II}: Excludes patents granted early in the period (before 2002) but traded later (after 2003).

^a *All Flows* considers for each multiply transacted patent, all its flows originating from the top 10 innovators, as separate ones.

^b *First Flow* considers, for each transacted patent originating from the top 10 innovators, only its first assignment, ignoring the rest of its transactions.

^c *Last Flow* considers, for each transacted patent originating from the top 10 innovators, only its last assignment, ignoring the rest of its transactions.

Next, we consider knowledge flows originating from the rest forty states, excluding flows originating from the top innovators. Estimates are displayed in Table 4. Results show that patent transaction flows originating from the lower innovative states are slightly less localized than the average state and top in-

novative state. In addition, comparing the *Dummy* coefficient between Table 3 and Table 4, we observe that it is smaller in the case of patent flows originating from the less innovative states compared to patent flows originating from the top innovative states. Moreover, the estimate of *Dummy* for the case of the less innovative states is negative in columns (4) and (5), though borderline significant.

Table 4: Geographical Effects of Patent Transaction Flows in the US (excl. top innovators)

	<i>All Patents</i> ^I			<i>Aged Patents Excluded</i> ^{II}		
	<i>All Flows</i> ^a	<i>First Flow</i> ^b	<i>Last Flow</i> ^c	<i>All Flows</i> ^a	<i>First Flow</i> ^b	<i>Last Flows</i> ^c
	(i)	(ii)	(iii)	(iv)	(v)	(vi)
<i>State Border</i>	-2.666*** (0.173)	-2.651*** (0.187)	-2.558*** (0.177)	-2.663*** (0.176)	-2.619*** (0.184)	-2.526*** (0.174)
<i>Nearby Area</i> [< 500 miles]	-2.952*** (0.148)	-2.919*** (0.155)	-2.917*** (0.152)	-2.944*** (0.150)	-2.874*** (0.152)	-2.863*** (0.148)
<i>Distance</i> [500 – 1,500 miles]	-3.326*** (0.151)	-3.307*** (0.162)	-3.219*** (0.157)	-3.321*** (0.153)	-3.268*** (0.159)	-3.176*** (0.155)
<i>Distance</i> [$> 1,500$ miles]	-3.664*** (0.150)	-3.698*** (0.155)	-3.562*** (0.153)	-3.664*** (0.151)	-3.663*** (0.152)	-3.523*** (0.149)
<i>Out of Country</i>	-1.111*** (0.169)	-1.065*** (0.177)	-0.904*** (0.170)	-1.122*** (0.170)	-1.065*** (0.173)	-0.902*** (0.166)
<i>Dummy</i>	0.362** (0.144)	0.310** (0.148)	0.326** (0.146)	-0.270* (0.146)	-0.246* (0.149)	-0.213 (0.147)
<i>State Border</i> \times <i>Dummy</i>	-0.0335 (0.208)	-0.0935 (0.223)	-0.184 (0.214)	-0.183 (0.217)	-0.201 (0.229)	-0.311 (0.221)
<i>Nearby Area</i> [< 500 miles] \times <i>Dummy</i>	0.0611 (0.190)	-0.0143 (0.195)	0.0457 (0.191)	0.0535 (0.198)	-0.0124 (0.201)	0.0199 (0.197)
<i>Distance</i> [500 – 1,500 miles] \times <i>Dummy</i>	0.0356 (0.184)	-0.000792 (0.192)	-0.0178 (0.187)	-0.0678 (0.183)	-0.0834 (0.190)	-0.130 (0.186)
<i>Distance</i> [$> 1,500$ miles] \times <i>Dummy</i>	0.354* (0.202)	0.333 (0.218)	0.266 (0.214)	0.374 (0.235)	0.389 (0.250)	0.315 (0.244)
<i>Out of Country</i> \times <i>Dummy</i>	0.476** (0.224)	0.460** (0.234)	0.362 (0.227)	0.542** (0.238)	0.529** (0.242)	0.407* (0.236)
<i>Constant</i>	3.028*** (0.121)	2.877*** (0.128)	2.818*** (0.127)	3.004*** (0.123)	2.826*** (0.125)	2.764*** (0.124)
Observations	34,112	34,112	34,112	34,112	34,236	34,251

All columns report negative binomial estimates and heterokcedastic robust standard errors (in parentheses). All regressions include time dummies and origin and destination state fixed-effects. *State Border* takes the value of 1 for flows exchanged between states i and j which are neighbors (share a common border) and 0 otherwise; *Nearby States* [500 miles] takes the value of 1 for flows exchanged between states that do not share a common border and their geographical centers are located within a distance of 500 miles, and 0 otherwise; *Distance* [500 – 1,500 miles] is a distance class of 500 to 1,500 miles and takes the value of 1 for flows exchanged between states i and j that are located within 500 to 1,500 miles distance class, and 0 otherwise; *Distance* [$> 1,500$ miles] is a distance classes of larger than 1,500 miles and takes the value of 1 for flows exchanged between states i and j that are located in a distance larger than 1,500 miles and 0 otherwise; *Out of Country* is a dummy and takes the value of 1, if a patent is traded between a state in the US and a foreign country, and 0 otherwise; *Dummy* is a time dummy variable which takes the value of 0 if a patent is traded in the period 1995-2002 and 1 if it is traded in the period 2003-2010; The variables *State Border* \times *Dummy*, *Nearby Area* [< 500 miles] \times *Dummy*, *Distance* [500 – 1,500 miles] \times *Dummy*, *Distance* [$> 1,500$ miles] \times *Dummy*, *Out of Country* \times *Dummy* are border-, distance-, region-time interaction terms. (***): significance at 1%, 5%, and 10% level, respectively. Top innovator states (which are excluded): California (CA), Massachusetts (MA), Michigan (MI), New Jersey (NJ), and New York (NY), Texas (TX), Illinois (IL), Pennsylvania (PA), Maryland (MD), Washington (WA), and Ohio (OH).

^I: All patent included.

^{II}: Excludes patents granted early in the period (before 2002) but traded later (after 2003).

^a *All Flows* considers for each multiply transacted patent, all its flows originating from the 40 less innovative states, as separate ones.

^b *First Flow* considers, for each transacted patent originating from the 40 less innovative states, only its first assignment, ignoring the rest of its transactions.

^c *Last Flow* considers, for each transacted patent originating from the 40 less innovative states, only its last assignment, ignoring the rest of its transactions.

The above comparison implies that flows originating from top innovators are on average more localized than flows originating from the less innovative states. This finding indicates that top innovators trade

more within the state than less innovative states, which potentially seek for buyers outside the state. This difference becomes even stronger, in more recent years as the coefficient of *Dummy* shows, where top innovators trade more within the state compared to less innovative states.

3.2. How Important is Geography for Patent Transactions across US Technological Sectors?

The estimates of the previous section showed a strong degree of localization of patent transactions. In this section, we dig deeper and investigate whether localization of patent exchange is still the case across six different technology fields namely, chemical (*Chemical*), computer and communication (*Computers*), drugs and medical (*Drug*), electrical and electronic components, (*Electronics*), mechanical machinery (*Mechanical*), and all other (*Others*) sector.¹⁵

Estimates are reported in Table 5 below and read in the same way as explained in the previous section.

Two noteworthy findings emerge from Table 5: first, there is no much variability of geographic and time effects across sectors, as estimates are similar across sectors and, second, sector-specific estimates are close and similar in statistical significance to aggregate (state level) estimates.

As sector-specific estimates show, state border continues to remain an important hurdle for patent transactions across all sectors, with *Drug* and *Others* to be the sectors most strongly affected as 94% of the patent trade in these sectors takes place in-state than across states, whereas the information technology sectors, *Electronics* and *Computers*, appear to be the least affected as 93% of the patent trade in these sectors takes place in-state than across states. The impact of geographic distance on trade of patents across US technology fields is even stronger. *Mechanical* and *Others* sectors are highly restricted by distance as, on average, distant states exchange 98% less patents compared to what they trade in-state. Patent exchange in *Computers* and *Electronics* is mildly more stretched in space compared to the rest of the sectors as distant states exchange about 97% less patents between each other in these sectors compared to what they trade within their state border. Therefore, inter-state patent trade is by far much smaller compared to in-state trade across all sectors and the former is massively restricted by state border and geographic distance.

¹⁵The patent classification in the six technology fields is based on their primary US Classification, which, in turn, relies on Hall et al. (2001).

Table 5: Geographical Effects of Patent Transactions across Technological Sectors (*All Flows*)

	<i>Chemical</i> (i)	<i>Computers</i> (ii)	<i>Drugs</i> (iii)	<i>Electronics</i> (iv)	<i>Mechanical</i> (v)	<i>Others</i> (vi)
<i>State Border</i>	-2.794*** (0.207)	-2.676*** (0.339)	-2.825*** (0.259)	-2.746*** (0.280)	-2.776*** (0.156)	-2.882*** (0.138)
<i>Nearby Area</i> [< 500 miles]	-3.387*** (0.188)	-3.667*** (0.211)	-3.413*** (0.225)	-3.326*** (0.189)	-3.443*** (0.146)	-3.498*** (0.130)
<i>Distance</i> [500 – 1,500 miles]	-3.784*** (0.175)	-3.585*** (0.227)	-3.726*** (0.198)	-3.807*** (0.184)	-3.836*** (0.136)	-3.944*** (0.113)
<i>Distance</i> [$> 1,500$ miles]	-3.794*** (0.190)	-3.216*** (0.201)	-3.471*** (0.208)	-3.311*** (0.179)	-3.841*** (0.144)	-4.002*** (0.120)
<i>Out of Country</i>	-1.057*** (0.198)	-0.623* (0.336)	-1.100*** (0.228)	-0.401 (0.328)	-1.497*** (0.172)	-1.558*** (0.158)
<i>Dummy</i>	0.210 (0.214)	0.998*** (0.261)	0.504* (0.261)	0.779*** (0.254)	0.603*** (0.209)	0.388*** (0.142)
<i>State Border</i> \times <i>Dummy</i>	0.152 (0.302)	-0.384 (0.454)	-0.321 (0.361)	-0.595 (0.382)	-0.325 (0.265)	-0.151 (0.196)
<i>Nearby Area</i> [< 500 miles] \times <i>Dummy</i>	-0.0525 (0.256)	-0.0660 (0.313)	0.259 (0.336)	-0.367 (0.309)	-0.314 (0.243)	-0.104 (0.184)
<i>Distance</i> [500 – 1,500 miles] \times <i>Dummy</i>	0.103 (0.240)	-0.462 (0.317)	-0.134 (0.290)	-0.282 (0.292)	-0.0821 (0.263)	0.0628 (0.163)
<i>Distance</i> [$> 1,500$ miles] \times <i>Dummy</i>	0.0902 (0.250)	0.0428 (0.306)	0.247 (0.300)	-0.222 (0.299)	0.0180 (0.240)	0.242 (0.183)
<i>Out of Country</i> \times <i>Dummy</i>	0.299 (0.272)	0.0543 (0.426)	0.294 (0.327)	0.00136 (0.425)	0.342 (0.279)	0.318 (0.226)
<i>Constant</i>	2.014*** (0.160)	2.232*** (0.172)	2.003*** (0.173)	1.944*** (0.152)	1.990*** (0.114)	2.438*** (0.0998)
Observations	42,432	42,432	42,432	42,432	42,432	42,432

All columns report negative binomial estimates and heteroskedastic robust standard errors (in parentheses). All regressions include time dummies and origin and destination state fixed-effects. *State Border* takes the value of 1 for flows exchanged between states i and j which are neighbors (share a common border) and 0 otherwise; *Nearby States* [500 miles] takes the value of 1 for flows exchanged between states that do not share a common border and their geographical centers are located within a distance of 500 miles, and 0 otherwise; *Distance* [500 – 1,500 miles] is a distance class of 500 to 1,500 miles and takes the value of 1 for flows exchanged between states i and j that are located within 500 to 1,500 miles distance class, and 0 otherwise; *Distance* [$> 1,500$ miles] is a distance classes of larger than 1,500 miles and takes the value of 1 for flows exchanged between states i and j that are located in a distance larger than 1,500 miles and 0 otherwise; *Out of Country* is a dummy and takes the value of 1, if a patent is traded between a state in the US and a foreign country, and 0 otherwise; *Dummy* is a time dummy variable which takes the value of 0 if a patent is traded in the period 1995-2002 and 1 if it is traded in the period 2003-2010; The variables *State Border* \times *Dummy*, *Nearby Area* [< 500 miles] \times *Dummy*, *Distance* [500 – 1,500 miles] \times *Dummy*, *Distance* [$> 1,500$ miles] \times *Dummy*, *Out of Country* \times *Dummy* are border-, distance-, region-time interaction terms. (***) : significance at 1%, 5%, and 10% level, respectively.

Overall, our sector-specific findings emphasize that patent transactions in all sectors are highly geographically confined. Among sectors, the geographic spread of patent transactions, and knowledge generated via traded patents, in the information technology sectors is the most far reached. A high degree of international standardization in computer language and computer procedures as well as in electronics, patent transactions in these sector reach farther in states and countries. *Mechanical* sector's technologies, on the other hand, are more linked to the specificities of regional economies and probably less engaged into globalization. Therefore, knowledge flows generated via patent transactions in this sector is less far reaching. Our findings about the localization of knowledge flows generated in US sectors are consistent with evidence provided from the (patent-citation) literature (Peri, 2005; Griffith et al., 2011).

3.3. Comparison with Citation Flows

To get a better sense of the size of our coefficients - as there is no study so far that has explored the geographic effects of patent transactions in the US - we compare, in this section, our patent trade geographic estimates with those of citations'. To this purpose, we estimate equation (1) for citation (of traded patents) flows across states in the US. Table 6 below presents our results based on state level (column (i)) and sector level (columns (ii) to (vii)) analyses. The coefficients are read in the same manner as before.

The state level estimates of citation flows in column (i) are somewhat smaller than that of their patent transaction counterparts reported in Table 2. The border and (average) distance effects on citation flows are about 2% and 5%, respectively, smaller than those of patent transaction flows. A further interesting geographic aspect of citation flows is that they are less restricted compared to patent transaction flows, when distance between states becomes more than 1,500 miles, as the California effect is at work. We cannot draw, however, any further conclusion over the time pattern of localization of citation flows, neither at a state nor at a national level as the time dummy and time-distance interaction terms are all statistically insignificant.

Moving to sector level analysis for citation flows performed in columns (ii) to (vii), the sector-specific border estimates are equal (*Drugs*) or up to 4-5% (*Mechanical & Others*) smaller than their patent transaction counterparts reported in Table 5. Compared to exchanging patents, neighboring states exchange more citations in these sectors. Therefore, state border confines citation flows less than it confines traded patent flows. Furthermore, citation flows are more far stretched in space by 4% (*Chemical, Drugs, and Electronics*) up to 7% (*Computers*) compared to traded patent flows. The California effect is also apparent for the sectoral citation flows - quite strong particularly for *Computers* and *Electronics*. Again, we cannot elaborate more on time patterns of sectoral citation flows - with the only exemption of *Electronics* sector where citation flows between a state and a foreign country have increased over time - as time dummy and interaction terms are, in all other cases, statistically insignificant.

Overall, we find that citation flows across states of the US are less geographically localized than flows of patent trade. Geographical distance severely reduces the volume of traded patents between East and West (California) Coast, whereas, it has a milder effect on citation flows. The potential need for the patent buyer to maintain contact with the inventor attaches a more nuance role to geography in shaping patent trade than shaping citations and consequent knowledge generated. To the extent that purchased patented technology plays a role in the buyer's production, distance and border could act as informational barriers, and serve as proxies for all types of informational frictions. Agents within a state tend to know much more about each other and each other's business and technologies, either because of direct interactions between their citizens or because of better media coverage. Therefore, distance and border also act as barriers to social connectedness (micro-cultural affinities) and networking of economic agents. Such social proximities have been identified in the literature (Saxenian, 1994) as important factors for knowledge exchange.¹⁶ Consequently, informal knowledge flows that operate via non-market mechanisms, such as exchange of citations, transcend easier a state border and are more diffused in space than formal knowledge flows that originate from market channels, such as patent transactions, as in the former case social proximities may play a less significant role.¹⁷

¹⁶Breschi and Lissoni (2004) apply a social network analysis to derive maps of social connectedness among patent inventors. The probability to observe a citation is positively influenced by social proximity of the inventors, as the authors argue.

¹⁷The origin of citations, i.e., whether are included by inventors or examiners on the patent document may have, however, different implications for the geographic stretched of citation flows. A study by Criscuolo and Verspagen (2008) examines patents from the European Patent Office (EPO) and exploits the distinction the EPO provides about the source of patent citations (since 1979). The authors find that inventor-origin citations are more geographically localized than their examiner-origin counterparts as inventors tend to choose their citations from within a narrower geographical space than examiners do. Consequently, a more detailed analysis on the reach of citation flows and to the extent that they represent actual knowledge and not 'noise', it would require the distinction into inventor- versus examiner-origin citations. The USPTO, however, has allowed such distinction only since 2001 (Alcacer and Gittelman, 2006; Thompson, 2006). Performing such analysis considerably restricts the data set and scope of this paper and, therefore, left for future investigation.

Table 6: Geographical Effects of Citation Flows across States in the US

	<i>States</i>	<i>Chemical</i>	<i>Computers</i>	<i>Drugs</i>	<i>Electronics</i>	<i>Mechanical</i>	<i>Others</i>
	(i)	(ii)	(iii)	(iv)	(v)	(vi)	(vii)
<i>State Border</i>	-2.472*** (0.211)	-2.524*** (0.182)	-2.349*** (0.261)	-2.891*** (0.235)	-2.540*** (0.241)	-2.351*** (0.194)	-2.310*** (0.176)
<i>Nearby Area</i> [< 500 miles]	-2.856*** (0.214)	-2.721*** (0.183)	-2.799*** (0.262)	-3.056*** (0.244)	-2.987*** (0.239)	-2.823*** (0.193)	-2.756*** (0.175)
<i>Distance</i> [500 – 1,500 miles]	-2.880*** (0.214)	-3.029*** (0.177)	-2.743*** (0.263)	-2.971*** (0.242)	-3.058*** (0.236)	-2.931*** (0.190)	-2.822*** (0.174)
<i>Distance</i> [$> 1,500$ miles]	-2.185*** (0.214)	-2.676*** (0.182)	-1.866*** (0.261)	-2.359*** (0.239)	-2.288*** (0.238)	-2.380*** (0.192)	-2.322*** (0.175)
<i>Out of Country</i>	0.269 (0.243)	0.113 (0.199)	0.477 (0.294)	-0.254 (0.266)	0.510* (0.268)	0.301 (0.216)	0.178 (0.199)
<i>Dummy</i>	-0.0191 (0.295)	-0.0844 (0.263)	-0.175 (0.368)	-0.0727 (0.347)	0.237 (0.333)	0.0653 (0.270)	0.181 (0.234)
<i>State Border</i> \times <i>Dummy</i>	0.102 (0.296)	0.139 (0.277)	0.0406 (0.370)	0.216 (0.348)	0.152 (0.350)	0.132 (0.283)	-0.0759 (0.245)
<i>Nearby Area</i> [< 500 miles] \times <i>Dummy</i>	-0.00770 (0.303)	-0.0510 (0.274)	0.0414 (0.376)	0.0736 (0.362)	0.0167 (0.345)	0.0533 (0.280)	-0.286 (0.243)
<i>Distance</i> [500 – 1,500 miles] \times <i>Dummy</i>	0.0838 (0.303)	0.179 (0.267)	0.109 (0.377)	0.196 (0.361)	0.0589 (0.341)	0.0464 (0.277)	-0.131 (0.242)
<i>Distance</i> [$> 1,500$ miles] \times <i>Dummy</i>	0.0786 (0.301)	0.172 (0.274)	0.0810 (0.373)	0.248 (0.353)	0.0584 (0.342)	0.0724 (0.278)	-0.120 (0.242)
<i>Out of Country</i> \times <i>Dummy</i>	-0.107 (0.349)	-0.148 (0.301)	-0.0426 (0.428)	-0.173 (0.396)	-0.0722 (0.389)	-0.123 (0.317)	-0.352 (0.277)
Constant	5.981*** (0.210)	3.641*** (0.173)	4.825*** (0.257)	4.422*** (0.233)	3.910*** (0.231)	3.719*** (0.186)	4.088*** (0.169)
Observations	42,432	42,432	42,432	42,432	42,432	42,432	42,432

All columns report negative binomial estimates and heteroscedastic robust standard errors (in parentheses). All regressions include time dummies and origin and destination state fixed-effects. *State Border* takes the value of 1 for flows exchanged between states i and j which are neighbors (share a common border) and 0 otherwise; *Nearby States* [500 miles] takes the value of 1 for flows exchanged between states that do not share a common border and their geographical centers are located within a distance of 500 miles, and 0 otherwise; *Distance* [500 – 1,500 miles] is a distance class of 500 to 1,500 miles and takes the value of 1 for flows exchanged between states i and j that are located within 500 to 1,500 miles distance class, and 0 otherwise; *Distance* [$> 1,500$ miles] is a distance classes of larger than 1,500 miles and takes the value of 1 for flows exchanged between states i and j that are located in a distance larger than 1,500 miles and 0 otherwise; *Dummy* is a time dummy variable which takes the value of 0 if a patent is traded in the period 1995-2002 and 1 if it is traded in the period 2003-2010; *Out of Country* is a dummy and takes the value of 1, if a patent is traded between a state in the US and a foreign country, and 0 otherwise; The variables *State Border* \times *Dummy*, *Nearby Area* [< 500 miles] \times *Dummy*, *Distance* [500 – 1,500 miles] \times *Dummy*, *Distance* [$> 1,500$ miles] \times *Dummy*, *Out of Country* \times *Dummy* are border-, distance-, region-time interaction terms. (***): significance at 1%, 5%, and 10% level, respectively.

Our evidence is in line with that documented in Mowery and Ziedonis (2001), the single study in the literature that examined the geographic reach of knowledge flows based on citation as well as on licensed university patent flows. Mowery and Ziedonis (2001) find that geographic distance matters more for university-generated knowledge flows that operate through the market of contracts (patent licenses) to university-generated knowledge flows that operate through non-market channels. Contrary to some arguments stated in the literature (Audretsch and Feldman, 1996, p. 651), we too find that geographic proximity is more essential to the operation of market contracts (trade of patents) compared to the operation of non-market flows based on citation flows.¹⁸

3.4. Agglomeration and Geographic Localization

At this point, we would like to add some additional consideration of the potential role of industry (sector) agglomeration in the localization effect in the trade of patents found earlier.¹⁹ Perhaps, patent transfer is more likely within a state simply because the majority of firms in an industry are also clustered in that state. Therefore, in this section we would like to further explore whether some technological sectors are more geographically concentrated than other sectors and whether the innovation status of a state (i.e., top v.s. low innovator) also relates to agglomeration issues.

In general, the terms "agglomeration" or "cluster" are used to refer to various forms of geographic concentrations (Fujita and Thisse, 2002; Martin and Sunley, 2003). The degree of concentration provides insights into the relative agglomeration or dispersion of a particular sector and into the respective levels of concentration between sectors. The literature offers several indices to measure the spatial concentration of activities, namely the concentration ratio, the Hirshman-Herfindhal index, the locational Gini coefficients, the Ellison and Glaeser (1997) concentration index, the location quotient among others.²⁰

We focus here on the most widely used measures, the locational Gini coefficient, the location quotient (LQ), and the Hirshman-Herfindhal Index (HHI). The output of a sector or state is the number of patents it produces and therefore we examine whether such production is concentrated in some sectors and some states. We begin with the locational Gini coefficient, which is defined as the maximum difference between the patent production (S_i^j) in sector i ($i = 1, \dots, 6$) in state j ($j = 1, \dots, 50$) and the total patent production (T_i) across all sectors in a given state. Formally,

$$Gini_i^j = 1/2 (\sum_{j=1}^{50} |S_i^j / \sum_{i=1}^6 S_i^j - T_i / \sum_{i=1}^6 T_i|).$$

It is a summary measure of spatial dispersion derived from a spatial Lorenz curve. Smaller values of locational Gini coefficient indicate similarity between spatial distribution of sector i and country's activity.

Table 7 below presents the locational Gini coefficient for the whole sample period, as well as for sub-periods, for six technological sectors.

Table 7: Concentration of Technological Sectors in the US (locational Gini coefficients)

period	Chemical	Computers	Drugs	Electronics	Mechanical	Others
1995-2010	0.144	0.181	0.174	0.135	0.171	0.103
1995-2002	0.141	0.195	0.159	0.133	0.151	0.093
2003-2010	0.147	0.167	0.189	0.138	0.191	0.113

¹⁸Audretsch and Feldman (1996) studied interactions between university-based scientists and biotechnology firms based on disclosures in firms' initial public offering documents about academic researchers' roles in the firms.

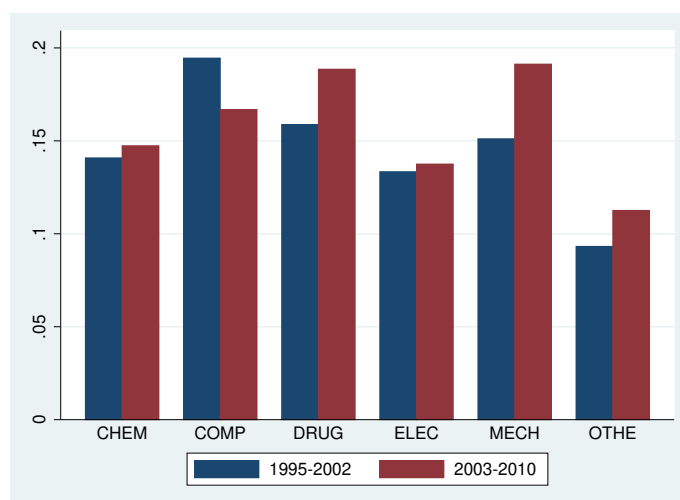
¹⁹We thank an anonymous referee who suggested such exploration.

²⁰See Kim et al. (2000), Marcon and Puech (2003), and Holmes and Stevens (2004) for a review.

We observe that the locational Gini coefficients do not vary much across technological sectors. Sectors such as *Others* and *Electronics* appear to be the least concentrated (agglomerated) as opposed to *Computers* and *Drugs*, which exhibit the highest concentration across states of the US. Over time, localization slightly increases, as sub-period Gini coefficients indicate, with the exception of the *Computers* sector, where the opposite effect takes place.

Figure 4 below graphically depicts the locational Gini coefficient in the two sub-periods: 1995-2002 (blue boxes) and 2003-2010 (red boxes).

Figure 4: Locational Gini Coefficient Over Time



Next, we proceed with examining whether there is agglomeration of innovation activity within a state. In doing so, we rely on the location quotient (LQ) index, which is another common approach to spatially delimit agglomeration. The LQ for sector i in region j is equal to the percentage of total patent production in region j devoted to sector i divided by the percentage of state's total patenting activity devoted to sector i . Formally,

$$LQ = \frac{s_i^j}{\sum_{i=1}^6 s_i^j} / \frac{T_i}{\sum_{i=1}^6 T_i}, \text{ where } i \text{ is sector } (i=1, \dots, 6), j \text{ is state } (j=1, \dots, 50).$$

A region is said to be specialized in one sector if it has an LQ over 1. In such a case, this sector is over-represented within this region. This property is used to identify agglomerations for a particular sector, which are then defined as the areas with high LQs for that sector.

In addition to LQ index, we also employ the Hirshman-Herfindhal index (HHI), which shows whether the production is concentrated in few or many firms and is calculated by summing the squared market shares of all of the firms in the industry. In our case, we sum up the squared market shares (s_i) of all technological sectors for each state j . Formally,

$$HHI = \sum_{i=1}^6 s_i^2.$$

The HHI ranges between 0 (low concentration) and 1 (high concentration).

Table A.2 in the Appendix provides the location quotient for the six technological fields (sectors) and HHI per state.

According to that Table, many states show LQ index higher than one and therefore exhibit some concentration especially in *Others* (35 out of 50 states) and *Mechanical* (33 out of 50 states) sectors, while only

few states (15 out of 50) show concentration in *Computers*.²¹

The top innovator states have HHI lower than the sample mean (0.249) and, therefore, exhibit less concentration with respect to the 'average' state. For the remaining 40 states, concentration patterns vary with respect to the sample mean, but overall, the dispersion of the HHI across states is rather small (0.044). Over time, there is not any noteworthy change neither in the HHI across states nor in its dispersion across states, as the HHIs indicate for the two sub-periods.

In sum, our evidence does not point to the emergence of significant agglomeration effect across geographic and technological space and time; so does the localization effect found earlier. The absence of variability in both patterns makes us cautious to establish a rigorous relationship between them.

4. Conclusion

Informal market channels of knowledge flows have received considerable attention in the economics of innovation. Studies have shown that they are significant components in the innovation process and that they are constrained by geographic distance; a result similar to the trade literature. In addition, some works have claimed that geographic distance plays a less significant role in recent years due to the increasingly interconnected world.

Using recently developed detailed data provided by the Office of the Chief Economist of re-assigned patents, we offer new insights on these important issues by adding a market channel of knowledge transfer, which has not yet comprehensively explored so far, the market of patents and knowledge flows based on patent transactions. We examine whether geographic and time effects shape patent transactions across states and sectors in the US and compare our findings with those of citation flows. Our results support that geographic nearness, in terms of distance and contingency, also matters for patent trade, as it has been massively documented in the trade and patent-citation literature. They further confirm that knowledge, generated from innovative ideas, which are patented and traded, are more geographically restricted and, therefore, their effective reach is less far stretched in space compared to knowledge flows based on citations. Although border and distance do not proxy transportation costs, as they do for goods trade - ideas are weightless - they could act as informational barriers, and therefore can hamper contacts and consequently patent transactions.

Our findings clearly support the presence of strong localization at a state level for patent transactions and to a lesser extent for citations. Although there is evidence of more patent trade in-state rather than across states, it is not, *per se*, a nuance evidence of higher importance of distance and border over time, neither for state nor for sector patent trade (and citation) flows. The information technology sectors, however, consist a notable exemption. We also explore whether industry agglomeration relates to geographic localization found in the trading of ideas. We found no rigorous association. Overall, our results remain robust across sub-samples and alternative specifications.

The next research challenge is to further explore the causes of localization of patent trade. The relationship of agglomeration and localization of patent trade deserves some further investigation. An issue deserving also further inquiry is the role of social proximity in shaping the trade of ideas. Learning more about the causes of localization is important for assessing welfare consequences. Furthermore, another important research avenue is the pursuit of the joint estimation of the geographic stretch of embodied and disembodied knowledge flows in one common framework and examine their individual effects on local production of innovation.

²¹The highest values of *LQ* appear in the state of Pennsylvania for *Chemical*, California for *Computers*, Maryland for *Drugs*, New York for *Electronics*, Michigan for *Mechanical*, and Illinois for *Others*.

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Appendix

Table A.1: Summary Statistics per State

State	<i>Traded Patents</i>		Citations		R&D activity	
	Mean	St. Dev.	Mean	St. Dev.	Mean	St. Dev.
AK	6.31	2.94	36.56	24.78	0.20	0.06
AL	88.13	47.23	1150.56	802.59	2.15	0.33
AR	31.94	20.16	281.88	179.00	0.40	0.06
AZ	176.88	95.16	2624.38	1658.99	3.07	1.05
CA	3395.44	1653.58	52919.94	35573.45	48.14	7.72
CO	333.50	135.23	5401.81	3507.14	4.14	0.78
CT	354.69	148.18	4146.00	2715.65	5.12	1.68
DE	663.63	476.70	3512.75	2273.66	1.50	0.40
FL	453.06	208.82	5418.50	3714.18	4.81	0.61
GA	233.56	103.64	3591.00	2484.46	2.81	0.73
HI	9.44	5.67	138.06	115.30	0.40	0.09
IA	89.75	47.08	1180.44	692.48	1.22	0.21
ID	129.38	159.94	2332.31	1680.63	1.01	0.31
IL	592.31	246.30	6348.94	4094.11	9.70	1.56
IN	179.25	78.99	2197.19	1532.68	3.61	0.78
KS	64.19	24.79	676.44	469.97	1.40	0.58
KY	52.13	34.06	583.31	503.72	0.81	0.23
LA	54.94	20.30	581.31	385.07	0.66	0.16
MA	879.38	484.82	12571.94	8350.31	13.11	2.07
MD	227.25	101.67	3157.50	2096.59	9.26	1.88
ME	20.88	17.07	234.31	168.39	0.28	0.11
MI	570.88	392.16	5921.00	4105.80	15.26	2.35
MN	493.13	217.75	8328.81	6168.83	4.40	1.06
MO	159.63	64.73	1166.94	747.70	2.43	0.41
MS	44.56	35.52	568.75	389.86	0.55	0.28
MT	17.50	9.83	264.75	204.21	0.18	0.06
NC	253.38	117.42	3240.00	2105.77	4.79	1.23
ND	11.19	6.52	111.38	80.54	0.20	0.12
NE	44.50	26.69	461.00	307.82	0.48	0.16
NH	114.38	66.78	1651.31	1131.31	1.11	0.46
NJ	675.81	256.10	8374.38	5269.52	11.59	1.18
NM	81.31	127.41	741.75	530.30	3.75	0.74
NV	247.44	226.62	2603.81	2202.51	0.46	0.14
NY	1037.44	411.97	13271.06	8551.06	12.86	0.89
OH	468.69	190.46	5107.56	3354.64	7.39	0.65
OK	54.56	29.19	870.75	563.34	0.67	0.10
OR	166.69	149.52	3353.69	2167.58	2.14	1.00
PA	551.06	213.11	6134.31	3904.21	9.58	0.92
RI	54.25	27.68	590.50	405.54	1.35	0.48
SC	67.13	36.01	704.50	467.85	1.22	0.37
SD	8.69	6.42	83.25	53.83	0.09	0.04
TN	162.44	74.06	1722.69	1199.70	2.18	0.57
TX	764.44	374.16	10631.50	6652.04	11.39	2.42
UT	130.38	64.14	2050.81	1467.04	1.34	0.29
VA	285.19	105.27	3088.69	2160.63	5.35	1.60
VT	13.44	8.92	310.50	175.95	0.39	0.08
WA	335.06	170.85	7067.44	5581.80	8.67	2.01
WI	195.69	84.22	2144.50	1467.90	2.77	0.54
WV	9.81	6.65	125.94	100.74	0.44	0.07
WY	11.50	6.44	94.25	63.34	0.08	0.02

First column is states' two-letter abbreviation; *Traded Patents* (of all types of patent flows) and *Citations* are occurrences; *R&D activity* is R&D spending (in billions of 2000 US dollars).

Table A.2: Indices of Concentration per State

State	Chemical	Computers	Drugs	Electronics	Mechanical	Others	<i>HHI</i>	<i>HHI</i> _{1995–2002}	<i>HHI</i> _{2002–2010}
	<i>LQ</i>								
AK	0.600	0.363	0.570	0.415	1.497	1.946	0.372	0.384	0.360
AL	0.989	0.742	1.037	0.649	1.286	1.260	0.219	0.226	0.211
AR	0.860	0.224	1.022	0.409	1.630	1.726	0.307	0.320	0.294
AZ	0.612	1.278	0.448	1.708	1.049	0.785	0.219	0.207	0.230
CA	0.705	1.391	1.114	1.206	0.635	0.816	0.213	0.194	0.231
CO	0.765	1.551	0.718	1.050	0.792	0.883	0.222	0.206	0.238
CT	1.370	0.616	1.301	1.017	1.207	0.964	0.183	0.187	0.178
DC	0.942	1.330	1.880	0.500	0.622	0.828	0.241	0.222	0.261
DE	4.101	0.176	1.605	0.359	0.709	0.728	0.285	0.322	0.247
FL	0.733	0.802	0.980	0.763	1.079	1.398	0.234	0.234	0.233
GA	1.040	0.948	0.804	0.552	0.993	1.327	0.242	0.247	0.237
HI	0.745	0.510	1.331	0.462	1.036	1.611	0.286	0.314	0.258
IA	0.698	0.629	1.831	0.594	1.417	1.169	0.216	0.221	0.212
ID	0.700	1.137	0.130	2.942	0.750	0.384	0.316	0.293	0.339
IL	1.027	0.814	0.687	0.790	1.210	1.319	0.223	0.221	0.224
IN	0.934	0.364	1.384	0.963	1.585	1.147	0.206	0.206	0.206
KS	0.834	0.882	0.724	0.469	1.148	1.430	0.268	0.279	0.258
KY	1.184	0.714	0.715	0.746	1.402	1.234	0.220	0.233	0.207
LA	1.838	0.203	0.887	0.343	1.301	1.597	0.283	0.276	0.290
MA	1.086	1.146	1.820	0.986	0.642	0.701	0.191	0.182	0.200
MD	1.204	0.924	2.220	0.677	0.815	0.774	0.193	0.194	0.192
ME	0.912	0.545	0.885	0.972	1.393	1.292	0.230	0.252	0.209
MI	0.874	0.436	0.470	0.837	2.873	1.000	0.237	0.236	0.238
MN	1.037	0.885	1.768	0.712	0.941	0.965	0.194	0.198	0.190
MO	1.196	0.384	1.449	0.576	1.274	1.343	0.228	0.236	0.220
MS	1.171	0.376	1.056	0.741	1.167	1.527	0.261	0.281	0.240
MT	1.622	0.280	0.926	0.402	1.382	1.523	0.271	0.281	0.260
NC	0.919	1.084	0.941	0.817	0.845	1.131	0.220	0.217	0.223
ND	0.748	0.396	0.507	0.441	2.572	1.389	0.289	0.317	0.260
NE	0.938	0.411	1.228	0.643	1.450	1.396	0.238	0.244	0.233
NH	0.695	1.093	0.719	1.170	1.279	0.927	0.205	0.194	0.215
NJ	1.510	1.193	1.475	0.641	0.637	0.845	0.198	0.187	0.208
NM	1.647	0.819	0.633	1.690	0.952	0.718	0.197	0.199	0.194
NV	0.532	0.414	0.469	0.655	0.958	2.058	0.372	0.341	0.403
NY	1.192	0.991	0.754	1.243	0.914	0.941	0.194	0.186	0.203
OH	1.522	0.297	0.803	0.705	1.551	1.365	0.235	0.236	0.233
OK	1.868	0.431	0.628	0.393	1.145	1.579	0.273	0.257	0.289
OR	0.507	1.467	0.373	1.233	0.904	1.023	0.242	0.237	0.246
PA	1.659	0.502	1.416	0.924	1.026	0.998	0.188	0.192	0.185
RI	0.904	0.651	0.639	0.821	1.115	1.538	0.259	0.238	0.279
SC	1.509	0.291	0.436	0.689	1.414	1.606	0.279	0.295	0.262
SD	0.487	0.585	0.589	0.687	1.826	1.516	0.282	0.303	0.260
TN	1.388	0.317	1.248	0.750	1.196	1.343	0.228	0.234	0.221
TX	0.955	1.483	0.525	1.200	0.649	0.906	0.224	0.207	0.241
UT	0.855	0.758	1.426	0.612	1.420	1.122	0.204	0.198	0.210
VA	1.006	1.034	0.714	0.872	1.239	1.055	0.207	0.205	0.209
VT	0.475	1.018	0.284	2.848	0.598	0.605	0.303	0.265	0.342
WA	0.579	1.443	0.927	0.689	0.889	1.010	0.246	0.206	0.286
WI	1.035	0.286	1.015	0.907	1.468	1.394	0.236	0.239	0.234
WV	3.208	0.212	0.519	0.442	1.291	1.163	0.270	0.291	0.249
WY	1.202	0.244	0.833	0.519	1.551	1.626	0.299	0.351	0.247

First column is states' two-letter abbreviation; *LQ*: Location Quotient; *HHI*: Hirshman-Herfindhal Index.