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Abstract:
The new trade theory literature (Markusen, 1984) suggests that R&D activities and production may be geographically separated. However, concurrent studies show a strong correlation between R&D and production (or exporting). This correlation is often attributed to border-induced disruptions in the flow of knowledge. Yet it is unclear whether the correlation between R&D and production (or exporting) is due to borders *per se* or to other factors. Surprisingly, researchers have yet to use subnational level data to investigate this point. This paper fills the gap by employing U.S. state-level data for 11 sectors over 1986-96 to examine this question. The results suggest that innovative activities are co-located with production and exporting at the subnational level. While this evidence cannot reject the Markusen model, it does indicate that innovation and production are not easily separated. Further, it suggests that the existing literature may overstate the importance of international borders and understate the role of subnational distance as impediments to spillovers.

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I. Introduction

Do firms have an incentive to co-locate research and development (R&D) activities and production? Despite a growing interest in economic geography, there is a surprising lack of analysis in this area. With the important exception of Markusen (1984), there is little theoretical work on this point. Markusen's model demonstrates that as long as transportation and trade costs outweigh plant economies of scale, firms will set up multiple and geographically dispersed plants. With the assumption that knowledge is easily transferable, production can be geographically separated from R&D. This prediction also comports with the intuition one might draw from the Hecksher-Ohlin model. To the extent that R&D is intensive in different factors than is production, we would expect to see research laboratories and production facilities separated across geographic space.

However, empirical studies find a positive relationship between a country's technological capacity and its ability to penetrate foreign markets (Soete, 1987; Dosi, Pavitt and Soete, 1990; and Eaton and Kortum, 1997). According to these studies, output and exports are closely tied to the extent of domestic R&D activity. Additionally, a growing literature demonstrates the disruptive effect national borders have on trade flows (McCallum, 1995), capital flows (Feldstein and Horioka, 1980) and movement of people (Helliwell, 1996 and 1997). Perhaps, then, what looks like co-location is really another border effect, with borders constraining firms' ability to separate research from production.

It is possible, therefore, that firms separate production from R&D but do so *within* national borders. Since the data are usually at the national level, we simply do not know whether firms co-locate research and production, or whether their attempt to separate the two activites is impeded by national borders. The best way to answer this question is to examine whether such correlation exists at the subnational level, since then there is no need to control for differences in industrial structures, regulations, intellectual property laws, and other country characteristics. Existence of such correlation in subnational data would suggest that factors other than international borders *per se* cause production plants to be located near R&D facilities. Surprisingly, researchers have yet to use subnational level data to test whether and to what extent borders are actually the barriers to knowledge flows.

This study fills this gap in the literature. We use U.S. state-level data for 11 manufacturing sectors over 1988-96 to examine whether R&D is geographically separated from production and exporting activities. The United States is an appropriate target for such analysis since it is a large economy both in geographic and economic terms. Our goal is to shed some light on how to interpret the studies relying on national data. If we find substantial geographic separation between R&D and production, there will be strong reason to believe that the aforementioned correlation between the two activities is an artifact of using national data, and it will suggest yet another way in which borders may influence economic activity. Conversely, evidence of co-location inside the U.S. would suggest that more work is needed in order to understand incentives driving firms' behavior. Finally, the empirical results may be useful to both economists and policy makers interested in knowing whether local R&D really does affect export performance or whether the correlation is a spurious artifact of the data.

Using established techniques, we find that technological specialization occurs in the same geographical area as production specialization, and as export specialization, as measured by revealed comparative advantage. Put roughly, innovative states are also the exporting states in most sectors, particularly the patent-intensive sectors. Our results imply strong incentives for co-location of innovative and production (and exporting) and reveal a need to reexamine the theoretical modeling of co-location.

While our evidence is preliminary and cannot reject the Markusen model, it does suggest qualifications to the literature on the border effect. First, innovation and production are not easily separated and there may be intra-national barriers to knowledge flows. Second, the empirical literature on innovative activity and exporting may overstate the importance of national borders and understate the role of subnational distance as impediments to spillovers from innovation to production and exporting. In other words, evidence that international borders limit these spillovers may at least partially be capturing the localization of such flows.

Additionally, the study establishes several stylized facts consistent with localized spillovers between innovation and exporting, and innovation and production. It also finds evidence of a fair degree of persistence in innovation, production, and exporting patterns, although these patterns have weakened a bit over time.

The paper is organized as follows. The following section includes a discussion of the literature. In section III we describe the data used in the analysis, and in section IV we present the empirical results on the relationship between the location of innovative activity and production. Section V includes a discussion of the results pertaining to innovative activity and exporting, and section VI provides the concluding remarks.

II. Literature

The geographic separation of innovative activity and production has been suggested by Markusen (1984) in his theory of multi-plant production arrangements. This theory emphasizes the public good nature of intangible assets owned by companies and assumes that blueprints are easily replicated and cheaply transported. It demonstrates that the existence of transportation costs leads firms to set up multiple geographically dispersed plants. This effect, however, is counterbalanced by the existence of plant scale economies that lead (ceteris paribus) to centralized production.

At the same time, the existing empirical literature has established a positive relationship between a country's technological capacity and its ability to penetrate foreign markets (Soete, 1987; Dosi, Pavitt and Soete, 1990; and Eaton and Kortum, 1997). These studies suggest that output and exports in a sector are closely tied to the extent of R&D activity in that sector. There is a lack of empirical evidence, however, as to whether this association holds at the subnational level.

The relationship between a country's technological capability and its ability to export has been the subject of a number of studies. Of these, Eaton and Kortum (1997) show that technology is an important factor determining international trade patterns and that a country's R&D stock is positively related to the value of its exports. Amendola, et al. (1998) find a positive relationship between the national patterns of technological accumulation and trade among the OECD countries.

Moreover, the literature on trade and technology patterns suggests that patterns of specialization, even if arbitrarily established, tend to persist overtime.[1] Most of the studies aiming to explain the interplay between technology and trade focus on cross-country analysis. Little attention has been paid to examining this relationship at the subnational level.

III. Data

This paper examines empirically whether production and exporting activities are geographically separated from innovative activities at the subnational level. For this purpose, we map local comparative advantages in patenting, production and exporting between 1988-96 by state and sector. We use the well-known 'revealed comparative advantage' (RCA) index, or a specialization index, developed by Balassa (1965).[2]

The RCA index has traditionally been a measure of the comparative advantage of a given country, say, the U.S., with respect to its trading partner. In this study, the index is used to measure the comparative advantage of a particular state relative to other states, with just one trading partner, simply, the rest of the world. Formally, RCA_{ij} is the index of revealed comparative advantage of state *i* in sector *j*

$$RCA_{ij} = \frac{X_{ij} / \sum_i X_{ij}}{\sum_j X_{ij} / \sum_i \sum_j X_{ij}} \qquad i\text{: state index, } j = \text{sector index}$$

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[1] See Krugman (1987), Pavitt (1988a), and Cantwell (1989). Krugman's (1987) trade model predicts that arbitrary patterns of specialization, once established, tend to persist and extend over time. Pavitt's theoretical and empirical work shows stability of international patterns of technological specialization over time. Pavitt's theory of technological accumulation is also supported by the empirical work of Cantwell (1989). Also, see Archibugi et al. (1998) for more on technological specialization at the industry level.

[2] See Dosi, et al. (1990) and Richardson and Zhang (1999) for detailed discussions of the RCA index.

The RCA index can offer a useful measure of a state's composition of output, exports and innovative activity and has been used to examine export specialization across countries in many studies (see for instance, Hoekman and Djankov, 1997; Richardson and Zhang, 1999). The index was also used to capture patenting patterns, which can be treated as a proxy for technological capacity (Amendola et al., 1998).

We construct the RCA indices for each state and sector, and thus we create a panel data set with state level observations over the period 1988-1996, including all fifty states. The eleven 2-digit SIC industries considered are food (20); textiles (22); chemicals (28); plastics and rubber (30); stone, clay and glass (32); primary metals (33); fabricated metals (34); industrial machinery and computers (35); electronics (36); transport equipment (37); and precision instruments (38). States' technological, production, and trade specializations are assessed with reference to this product set.

To calculate RCA in innovation, we use the number of patents granted in a given state and sector as an indicator of technological output. While using patents as a measure of innovative capacity has some disadvantages,[3] patenting activity allows for a uniform comparison of the innovative capacities of U.S. states. We define the RCA for patenting as the ratio of a state's share of U.S. patents in a given sector to a state's share of total U.S. patents (in all sectors). In other words, for our purposes the RCA index is a ratio of ratios that measures the relative competitiveness of one state's industry to its other industries relative to national norms.

Using patent data at the state level has many advantages. State level data allow for a uniform and consistent comparison of technological activities across geographical units, since all states are subject to identical patent laws and practices.[4] While the world's patenting systems are slowly coming together, legal and institutional differences between national systems may affect the comparability of historical international patent data.[5] One shortcoming of state-level data is that relevant boundaries of economic regions do not respect state boundaries. For example, the textile industry occupies the Piedmont area in the southeast of the United States, and state data do not necessarily reveal the compactness of that industry's location. However, despite such limitations, which pale in comparison to the difficulties in comparable studies of international flows, we can still learn quite a lot from state-level data.

The patent data come from the U.S. Patent and Trademark Office (PTO) and are organized by state and sector. State patent data are based on the location of the first-named inventor, which avoids the problem of inflation of patents for states in which there are a relatively large number of patent attorneys. The U.S. patents are classified according to the U.S. Patent Classification, which PTO has concorded to the U.S. Standard Industry Classification. In order to avoid multiple patent counts among product field categories, thereby introducing measurement error into the patenting RCAs, we use PTO's "fractional counts" data set as opposed to the "whole counts" data set. In the latter, a single patent may be counted in the profiles of as many as seven unique SIC-based

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[3] See Soete (1987), Pavitt (1988a,b), and Cantwell (1989) for a discussion.

[4] Technically, trade secret protection varies across states, but the differences are insignificant for this study. A vast majority of states have adopted the Uniform Trade Secret Act, and other states have a law or laws similar to the Uniform Act. Forty-four states have adopted the Uniform Act, others protect trade secrets under Common Law (New Jersey, New York, Pennsylvania, Texas, Wyoming), or have a trade secret law that is not modeled after the Uniform Act (Massachusetts). Overall, differences in trade secret laws across states are not strong enough to affect firm's location decisions. See "A Few Facts about the Uniform Trade Secrets Act," National Conference of Commissioners, Chicago, Illinois, 2000.

[5] See Evenson (1984).

product fields, while ‘fractional counts’ profiles eliminates multiple counting of patents across product fields by dividing each patent equally among the SIC-based product fields to the patent’s ‘original’ USPCS subclass.[6] Patent data used in this study are at the 2-digit SIC level.

Similarly, we measure a state’s production specialization in a sector by its revealed comparative advantage in production in that sector. We use the value-added production data as a proxy for output, and compiled the data from the U.S. Census Bureau, Annual Survey of Manufactures (ASM). The ASM provides sample estimates of statistics for all manufacturing establishments with one or more paid employees at the 2- and 3-digit SIC level.[7] Unlike the data for value of shipments, which include varying amounts of duplication, especially at higher levels of aggregation, the value-added statistics avoid the duplication and are, for our purposes, the best measure for comparing the relative economic importance of industries and geographic areas.

The state export data are from the Massachusetts Institute for Social and Economic Research (MISER) at the University of Massachusetts. MISER improves the unadjusted trade data from the U.S. Census Bureau by filling in missing industry and state information using an imputation algorithm approved by the Census Bureau. Despite the limitations of the data,[8] the adjusted MISER origin of movement data is generally

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[6] For example, in the “whole counts” product field profiles, a patent is counted if the patent’s ‘original’ USPCS subclass is matched, via concordance, to that product field. If a patent has an ‘original’ classification in a USPCS subclass that is matched to 3 unique SIC-based product fields, that patent would be counted once in each of the three associated ‘whole counts’ profiles; consequently, multiple counting is a result.

[7] The assembly of components into new products is considered manufacturing, except when it is appropriately classified as construction.

[8] The source of the data is the Shippers Export Declaration, which asks for “the state where the product began its journey to the point of export.” That state is not necessarily the state of the manufacture or where the product was grown or mined. It may in some cases be the state of a broker or wholesaler or state of

acknowledged as the best available data on state exports. The data set is available at the 2-digit SIC level.

IV. Evidence on Patenting and Exporting Patterns

Descriptive Statistics

We begin our analysis with some descriptive statistics. Table 1 shows the states with the top 5 patenting, exporting and production shares in 1988, 1992, and 1996. Not surprisingly, these statistics indicate that larger states tend to patent, export and produce more. The three largest states (California, New York, Texas) held the top 4 patenting and exporting shares over 1992-1996. Additionally, there is a lot of overlap between the top 5 patenting and exporting states during this period. This observation also holds at the sectoral level. The bottom of Table 1 shows that the larger states have had top patenting, production, and exporting shares in most sectors in 1996.[9] These figures correspond to the findings of studies based on international data. For instance, Archibugi et al. (1998) illustrated that larger countries have the largest shares of patenting and exporting in most sectors.

Table 2 presents three measures of patent intensity by industry: industry shares of total patents granted in each sector, the number of patents per value of shipments, and the number of patents per value-added production for 1988, 1992, and 1996. It is interesting to note that the rankings are about the same across the three measures. The most patent-

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consolidation of shipments. This issue results in some inflation of exports for the major port states and understatement of exports for other states. Indeed, it is the reason why Louisiana is the 9th largest exporting state according to the data, since agricultural crops from interior states are shipped via the Mississippi River and leave the U.S. through Louisiana. The problem is most acute for agricultural shipments and less so for manufactured exports.

intensive sectors include industrial machinery/computers, electronics, precision instruments and chemicals. Textiles, food, and primary metals are the least patent-intensive industries. Considering patent grants as technological output, the most (least) patent-intensive sectors can be considered the high- (low-) technology sectors.[10] A comparison of the patent intensities with the states' patent shares suggests that the larger states have a greater patenting presence in the most patent-intensive sectors than in the least patent-intensive sectors.[11] This says nothing, however, about comparative advantage.

We use the numerator of the RCA index to examine whether innovative activity occurs in the same place as production and exporting. We examine the correlation between a state's national share in each sector of patenting and exporting, and patenting and production, by sector and year. The average of the correlations for 1988, 1992, and 1996 for each industry is reported in Table 3 in descending order (the correlations change very little over time in each sector). While this share measure is a less-refined measure than the RCA, the numbers are informative. The correlation statistics reveal that the most (least) patent-intensive sectors possess the highest (lowest) correlation between patenting and exporting, and patenting and production. Patenting activity appears to be geographically located near production and exporting to a much greater degree in the high-tech sectors than in the low-tech sectors.

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[9] This also holds for 1988 and 1992 but the figures are not shown for brevity.

[10] Patenting is an imperfect measure of technological output since the shares of inventions patented may vary between industries (see Levin, 1986; Griliches, 1990).

Concentration of Sectoral Patterns of Geographical Specialization

Next, we turn to geographical concentration. An analysis of the variances of patenting, exporting and production RCA's by sector is useful in examining the degree of geographical concentration of each sector. High values of the variance reveal strong specialization in some states, and weak specialization in others; in other words, specialization is geographically concentrated in a few areas. Low values of the variance indicate that specialization is more evenly spread out across states, and that no one state is strongly specialized in that industry.

Table 4 reports the average variances of RCA indices across states by sector over 1988-1996. So as not to reflect differences in indices across sectors, these figures were weighted by the averages of their respective RCA index. Several interesting observations emerge from this level of analysis. First, greater variance can be observed in the exporting RCAs than in the patenting RCAs in every sector. This means that the RCA export index is very high in some states, and very low in other states, while the RCA patent index doesn't vary as much. In other words, states tend to be relatively more diversified in their patenting activities than in their production activities, which may be due to the fact that undertaking production is associated with the need to develop technological interdependencies with suppliers, partners, and clients. This result is also consistent with country-level findings (e.g., see Amendola, et al., 1998; and Pavitt and Townsend, 1989).

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[11] This may be because the low technology sectors rely more heavily on natural resources and low skilled labor while the high-technology sectors locate near other economic activity to realize agglomeration effects. However, we do not explore rigorously such possibilities in this paper.

Second, in reviewing the variances of patenting RCA and exporting RCA by sector, we find that the greatest geographical concentration in patenting and exporting is in the least patent-intensive sectors. A ranking of the variances as shown in Table 4 indicates that the sectors with the three highest variances in exporting also have the three highest variances in patenting. A sector in which there are states with very high RCA's and states with very low RCA's corresponds to a high variance in that sector. Perhaps not surprisingly, these three sectors are food, textiles, and primary metals, all relatively resource-based sectors. Consider textiles, the least patent-intensive sector. Krugman (1991) described the geographic concentration of this industry in southeast area of the U.S. Not only is the industry geographically concentrated in the Piedmont area, as Krugman discussed, and as our descriptive statistics illustrate, but our results show that the geographic trade and technological specialization are also in this area (North Carolina, South Carolina and Georgia have the highest three patenting, exporting and production RCA indices in textiles).

However, geographic concentration is not necessarily related to revealed comparative advantage. Consider a high-tech sector, say, computers and industrial machinery, which is geographically concentrated in Silicon Valley. The states with the top 5 patenting RCAs in 1996 were North Dakota, South Dakota, Kentucky, Wyoming, and Oregon. In terms of exports, the states with the top 5 RCA's in this sector were North Dakota, Idaho, New Hampshire, Wisconsin, and South Dakota; and, in terms of production, South Dakota, North Dakota, Idaho, Wisconsin, and Iowa. This admittedly crude example illustrates that geographic concentration is not necessarily related to RCA.

While our results suggest that this may be the case in low-tech sectors, it is clearly not the case in general.

Patterns of Trade and Technological Specialization

It is well-established that geographic concentration is a stable feature of the spatial distribution of economic activity in the U.S. (see Krugman, 1987 and 1991; Hanson, 1998). There is also convincing empirical evidence that countries exhibit stable patterns of technological specialization over time (Pavitt, 1988; Amendola et al., 1998). However, we are aware of no evidence that sectoral patterns of geographical specialization of trade and technology at the local level are stable over time.

In this section, we test the hypothesis that sectoral patterns of geographical specialization evolve gradually. For this purpose, we employ the technique known as the Galtonian regression model, which allows us to examine whether the specialization vectors of each sector are stable or whether they tend to change over time.[12] The state (spatial) distributions of each specialization indicator are compared in two different periods, estimating simple cross-section regressions. More formally, the following regression was estimated for each of the eleven sectors:

$$Y_{T2} = a + bY_{T1} + \mathrm{u}_t \qquad (1)$$

where $T1$ and $T2$ denote the averages for the periods 1988-1990 and 1994-1996, respectively. Y refers to the RCA indices for patenting, production and exporting. Separate regressions are estimated for each type of RCA index.

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[12] Amendola et al. (1998) applied the Galtonian regression model to test national patterns of specialization. We adapt their methodology and modify the approach to test sectoral patterns of specialization.

Table 5 reports the estimation results for each of the eleven industries. The null hypothesis of perfect stability in the geographic structure of trade (production or technological) specialization corresponds to a regression coefficient (*b*) of unity. Values of *b* greater than 1 indicate increasing specialization in a given sector. Values of *b* between 0 and 1 indicate a weakening of specialization, while values below 0 suggest that the ranking of states has changed drastically.[13]

Stability in the location of patenting activities would suggest a coefficient of unity. However, as shown in Table 5 indicates, plastics/rubber, and electronics are the only two sectors in which the coefficient on lagged RCA in patenting is not significantly different from one. In all regressions the estimated coefficients are between 0 and 1 (or not significantly different from one) which suggests persisting, although weakening, specialization patterns. The smallest coefficients can be found in stone, clay and glass and in primary metals sectors. These are some of the least-patent intensive industries. It is worth noting, however, that in another low-patent intensive industry, namely textiles, the magnitude of the coefficient is quite large. It is also worth noting that Markusen's multi-plant model, in which R&D activities can take place in the firm's headquarters and new plants serve the geographic areas in which they locate, would suggest stability unless there are many new entrants into the industry.

Similarly, in the value-added production regressions, all coefficients are between 0 and 1, suggesting some changes in the geographic distribution of production patterns. In four cases out of 11, however, we cannot reject the hypothesis that the coefficient is

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[13] See Cantwell (1989) and Amendola et al. (1998) for details on the methodology of the testing procedure adapted here.

equal to one, which implies stability of production patterns. These sectors are some of the most technology-intensive industries, namely, chemicals, industrial machinery and computers, and electronics, as well as stone, clay and glass sector. In the latter case, the observed stability may be associated with availability of natural resources.

The exporting regressions yield similar results. They indicate stability in three sectors (chemicals, transportation and primary metals) and weakening specialization patterns in other industries.

Thus, overall, the estimation results reveal that states have generally exhibited a stable pattern of technological, export, and production specialization over time. Such persistence in innovation, production and exporting patterns which, albeit have also weakened over time, correspond to previous authors' findings at the cross-country level.

Technological Specialization as a Determinant of Production Specialization

In this section, we examine empirically whether technological specialization of states is related to their production specialization patterns. Recall also that simple share measures (in Table 3) suggest that this is more likely to be the case for the low-tech sectors than for the high-tech sectors. Here we use RCA indices in a more thorough analysis of this question. We estimate a model that relates RCA in production to a lagged (by one or two years) RCA in patenting.

$$\mathrm{RCAVA}_{i,t} = a + b\mathrm{RCAP}_{i,t-j} + \mathrm{u}_t \qquad \mathrm{i} = 1, \ldots, \mathrm{N};\ j = 1, 2 \qquad (2)$$

where i is the state index. The lagged value of patenting RCA reflects that it may take time to introduce newly patented products into the production process. So as not to impose identical technological and trade structures on each industry, equation (2) is estimated separately for each sector. Standard errors are corrected to reflect possible correlation between residuals for observations for the same state in each regression.

The results, presented in Table 6, illustrate a strong correlation between innovative activity and production. A positive and significant coefficient here means that a state that has a relative technological specialization in a particular sector also tends to have a large share of national production in that sector relative to the total production in that state. The coefficients are significant and positive in 8 out of 11 sectors. Only in the regressions for transport equipment, fabricated metals and stone, clay and glass, are the coefficients statistically insignificant. It is noteworthy that the largest coefficients can be found in the four most patent-intensive sectors, namely in precision instruments, electronics, industrial machinery and computers, and chemicals. These findings reveal a strong relationship between a state's technological specialization and its production performance. This seems to contradict conclusions of Markusen's model, which suggests geographical separation of R&D activities and production.

Technological Specialization as a Determinant of Trade Specialization

Next, we examine the relationship between a state's technological specialization and its trade specialization at the sectoral level. We estimate regressions analogous to the ones presented in the preceding section. The estimation results, presented in Table 7, illustrate that exporting RCA is positively and significantly related to the patenting RCA in all sectors, with, again, the exception of transportation, fabricated metals, and stone, clay and glass. Thus, there exists a positive and significant relationship between a state's technological specialization and export specialization in most sectors. The largest coefficients are in the most patent-intensive sectors (electronics, instruments, and chemicals).

VII. Concluding Remarks

The new trade theory literature (Markusen, 1984) suggests that R&D activities and production may be geographically separated. At the same time, many empirical studies show a strong correlation between innovative activity and exporting at the national level. It is often assumed that this correlation is due to the border effects, since there is a vast literature indicating that borders disrupt the flows of trade, capital, and people. So far no effort has been made at testing whether the co-location of innovation and exporting is due to the border effect per se or to other factors. We attempt to fill this gap in the literature and examine the relationship between revealed comparative advantage (RCA) indices in patenting, exporting, and production at the subnational level using US state data for 11 manufacturing sectors over 1988-1996.

Our preliminary findings suggest a positive and significant relationship between innovative activity, as measured by patenting, and exporting, and innovative activity and production at the subnational level. While this evidence cannot reject the Markusen model, it does indicate that innovation and production are not easily separated. Further, the data suggest that the empirical literature on innovative activity and exporting may overstate the importance of national borders and understate the role of subnational distance as impediments to spillovers.

Additionally, we establish the following stylized facts about patenting, exporting, and production trends at the local level.

(i) states tend to be relatively more diversified in their patenting activities than in their production activities;

(ii) patenting appears to be geographically located near production and exporting activities to a much greater degree in the high-tech sectors than in the low-tech sectors;

(iii) the greatest geographical concentration in patenting and exporting activities are in least patent-intensive sectors;

(iv) there is persistence of innovation, production and exporting patterns which has diminished over time;

(v) there is a positive and significant relationship between a state's technological specialization and production specialization, and between a state's technological specialization and export specialization. This relationship is the strongest in the most patent-intensive sectors.

Information on geographical patterns of patenting and exporting, and the relationship between patenting RCA and exporting RCA may provide insightful policy implications. However, the scope for policy action from the preliminary findings presented above is limited. At best, it may indicate that it may be too early to talk about the "death of distance" since we find, at the industry-level, that patenting activity tends to occur in the same place as production. So, while information may flow freely, our findings imply that "know-how" does not, and the engineers are still on the production floor. Distance matters – even at the subnational level.

References

Amendola, Giovanni, Paolo Guerrieri, and Pier Carlo Padoan, 1998. "International Patterns of Technological Accumulation and Trade," *in Trade, Growth, and Technical Change*, edited by Daniele Archibugi and Jonathan Michie, Cambridge University Press.

Archibugi, Daniele and Mario Pianta, 1998. "Aggregated Convergence and Sectoral Specialization in Innovation: Evidence for Industrial Countries," in *Trade, Growth and Technical Change,* edited by Daniele Archibugi and Jonathan Michie, Cambridge University Press.

Balassa, Bela, 1965. "Trade Liberalization and Revealed Comparative Advantage," *The Manchester School of Economic and Social Studies,* v33, n3, pp.99-124.

Cantwell, John, 1989. *Technological Innovation and Multinational Corporations,* Oxford and Cambridge, Massachusetts: Blackwell.

Dosi, Giovanni, Keith Pavitt, and Luc Soete, 1990. "Technology Gaps, Cost-Based Adjustments and International Trade," in *The Economics of Technical Change and International Trade,* edited by Giovanni Dosi, Keith Pavitt, and Luc Soete, New York: New York University Press.

Eaton, Jonathan and Samuel Kortum, 1997. "Technology and Bilateral Trade," NBER Working Paper No. 6253.

Evenson, 1984. "International Invention: Implications for Technology Market Analysis," in *R&D, Patents, and Productivity*, NBER Conference Report, edited by Zvi Griliches, Chicago and London: University of Chicago Press.

Feldstein, Martin and Charles Horioka, 1980. "Domestic Savings and International Capital Flows," *Economic Journal,* v90, n358, pp. 314-29.

Griliches, Zvi, 1990. "Patent Statistics as Economic Indicators: A Survey," *Journal of Economic Literature*, v28, n4, pp.1661-1707.

Hanson, Gordon, 1998. "Market Potential, Increasing Return, and Geographic Concentration," NBER Working Paper No. 6429.

Helliwell, John F., 1996. "Do National Borders Matter for Quebec's Trade?" *Canadian Journal of Economics*, v29, pp. 507-22.

Helliwell, John F., 1997. "National Borders, Trade and Migration," NBER Working Paper no. 6027.

Hoekman, Bernard and Simeon Djankov, 1997. “Determinants of the Export Structure of Countries in Central and Eastern Europe,” *The World Bank Economic Review,* v11, n3: pp. 471-87.

Krugman, Paul, 1987. “The Narrow Moving Band, the Dutch Disease, and the Competitive Consequences of Mrs. Thatcher,” *Journal of Development Economics*, v27, n1-2, pp. 41-55.

Krugman, Paul, 1991. *Geography and Trade*, Cambridge: The MIT Press.

Levin, Richard C., 1986. “A New Look at the Patent System,” American Economic Review, v76, n2, pp. 199-202.

Markusen, James R. 1984. “Multinationals, Multi-Plant Economies, and the Gains from Trade,” *Journal of International Economics,* v16, pp. 205-226.

McCallum, John, 1995. “National Borders Matter: Canada-U.S. Regional Trade Patterns, *American Economic Review,* v85, pp. 615-623.

Pavitt, Keith, 1988a. “International Patterns of Technological Accumulations,” in *Strategies in Global Competition,* edited by N. Hood and JE Vahlne, London: Croom Helm.

Pavitt, Keith, 1988b. “Uses and Abuses of Patent Statistics,” in *Handbook of Quantitative Studies of Science and Technology,* edited by A. Van Rann, Amsterdam: Elsevier.

Pavitt, Keith and J. Townsend, 1989. “Accumulation, Diversification and Organization of Technological Activities in UK Companies,” in *Technology Strategy and the Firm: Management and Public Policy,* edited by M. Dogson, Harlow: Longman.

Richardson, J. David and Chi Zhang, 1999. “Revealing Comparative Advantage: Chaotic or Coherent Patterns across Time and Sector and U.S. Trading Partner?” NBER Working Paper No. 7212.

Soete, L. 1987. “The Impact of Technological Innovation on International Trade Patterns: the Evidence Reconsidered,” *Research Policy*, v16, n2-4, pp. 101-130.

Table 1. Patent, Export and Production Shares of Top 5 States, 1988, 1992, 1996

Patent Shares						Export Shares						Production Shares					
1988		1992		1996		1988		1992		1996		1988		1992		1996	
CA	0.15	CA	0.15	CA	0.18	CA	0.16	CA	0.17	CA	0.18	CA	0.12	CA	0.11	CA	0.11
NY	0.08	NY	0.09	NY	0.09	TX	0.12	TX	0.12	TX	0.13	OH	0.07	OH	0.07	TX	0.07
NJ	0.07	TX	0.06	TX	0.07	NY	0.09	WA	0.07	NY	0.06	TX	0.06	TX	0.06	OH	0.07
PA	0.06	NJ	0.06	MI	0.05	MI	0.08	NY	0.06	MI	0.06	NY	0.06	MI	0.06	IL	0.06
IL	0.06	IL	0.05	NJ	0.05	WA	0.05	MI	0.06	IL	0.05	MI	0.06	IL	0.06	MI	0.06

	Patent Shares		Export Shares		Production Shares
Industry	1996	Industry	1996	Industry	1996
Electronics	CA, TX, NY, IL, NJ	Electronics	CA, TX, IL, AZ, FL	Electronics	CA, TX, PA, IL, MI
Industrial Mach.	CA, TX, NY, IL, MI	Industrial Mach.	CA, TX, IL, NY, FL	Industrial Mach.	CA, TX, IL, OH, MI
Instruments	CA, NY, MA, TX, MN	Instruments	CA, NY, TX, MA, FL	Instruments	CA, NY, MA, TX, FL
Chemicals	CA, NJ, PA, NY, OH	Chemicals	TX, NJ, CA, LA, IL	Chemicals	TX, NJ, NC, IL, CA
Fab. Metals	CA, MI, NY, IL, TX	Fab. Metals	TX, CA, OH, MI, IL	Fab. Metals	OH, CA, MI, IL, PA
Transportation	MI, CA, IL, OH, FL	Transportation	MI, WA, CA, OH, TX	Transportation	MI, OH, CA, IN, MO
Rubber/Plastics	CA, OH, NY, MI, PA	Rubber/Plastics	TX, CA, OH, IL, SC	Rubber/Plastics	OH, CA, IL, MI, TX
Stone	NY, CA, OH, IL, MI	Stone	OH, PA, TX, CA, MI	Stone	CA, TX, OH, PA, NC
Food	NJ, IL, CA, MN, OH	Food	CA, LA, TX, WA, FL	Food	CA, IL, TX, OH, PA
Primary Metals	OH, CA, PA, NJ, MI	Primary Metals	NY, TX, CA, PA, UT	Primary Metals	OH, IN, PA, MI, IL
Textiles	GA, NC, SC, CA, OH	Textiles	NC, GA, TX, SC, NY	Textiles	NC, GA, SC, AL, VA

Table 2: Measures of Patent Intensities

Industry Shares of Total Patents, in Descending Order

1988			1992			1996		
SIC	Description	Share	SIC	SIC Description	Share	SIC	SIC Description	Share
35	Industrial Machinery/Computers	0.237	35	Industrial Machinery/Computers	0.231	36	Electronics	0.252
36	Electronics	0.228	36	Electronics	0.222	35	Industrial Machinery/Computers	0.237
38	Precision Instruments	0.145	28	Chemicals	0.159	38	Precision Instruments	0.163
28	Chemicals	0.145	38	Precision Instruments	0.155	28	Chemicals	0.147
34	Fabricated Metals	0.098	34	Fabricated Metals	0.087	34	Fabricated Metals	0.072
37	Transport Equip.	0.051	30	Rubber/Plastic Products	0.051	37	Transportation Equip.	0.047
30	Rubber/Plastic Products	0.049	37	Transportation Equip.	0.050	30	Rubber/Plastic Products	0.042
32	Stone, Clay, Glass	0.020	32	Stone, Clay, Glass	0.021	32	Stone, Clay, Glass	0.019
33	Primary Metals	0.012	33	Primary Metals	0.010	20	Food	0.008
20	Food	0.009	20	Food	0.009	33	Primary Metals	0.007
22	Textiles	0.007	22	Textiles	0.006	22	Textiles	0.006

Number of Patents/Value of Shipments, by Industry, in Descending Order (E+10)

1988			1992			1996		
SIC	Description		SIC	Description		SIC	Description	
38	Precision Instruments	462.6	38	Precision Instruments	533.8	38	Precision Instruments	591.1
36	Electronics	437.4	36	Electronics	486.6	36	Electronics	448.2
35	Industrial Machinery/Computers	351.0	35	Industrial Machinery/Computers	414.5	35	Industrial Machinery/Computers	338.5
34	Fabricated Metals	221.7	34	Fabricated Metals	243.7	28	Chemicals	218.4
28	Chemicals	202.1	28	Chemicals	242.5	34	Fabricated Metals	184.7
30	Rubber/Plastic Products	189.4	30	Rubber/Plastic Products	207.5	30	Rubber/Plastic Products	154.3
32	Stone, Clay, Glass	120.4	32	Stone, Clay, Glass	154.0	32	Stone, Clay, Glass	126.0
22	Textiles	58.1	37	Transportation Equip.	65.0	37	Transportation Equip.	58.4
37	Transportation Equip.	54.9	22	Textiles	39.1	22	Textiles	46.1
33	Primary Metals	29.0	33	Primary Metals	32.3	33	Primary Metals	21.4
20	Food	9.2	20	Food	10.1	20	Food	8.9

Table 2: Measures of Patent Intensities, Continued

Number of Patents/Value-Added Production, by Industry, in Descending Order (E+6)

1988			1992			1996		
SIC	**Description**		**SIC**	**Description**		**SIC**	**Description**	
36	Electronics	79	36	Electronics	87	38	Precision Instruments	91
38	Precision Instruments	70	35	Industrial Machinery/Computers	81	36	Electronics	79
35	Industrial Machinery/Computers	66	38	Precision Instruments	80	35	Industrial Machinery/Computers	69
34	Fabricated Metals	44	34	Fabricated Metals	48	28	Chemicals	41
30	Rubber/Plastic Products	38	28	Chemicals	45	34	Fabricated Metals	37
28	Chemicals	38	30	Rubber/Plastic Products	40	30	Rubber/Plastic Products	31
32	Stone, Clay, Glass	22	32	Stone, Clay, Glass	28	32	Stone, Clay, Glass	23
22	Textiles	14	37	Transportation Equip.	16	37	Transportation Equip.	16
37	Transportation Equip.	13	22	Textiles	9	22	Textiles	12
33	Primary Metals	8	33	Primary Metals	9	33	Primary Metals	5
20	Food	2	20	Food	3	20	Food	2

Table 3. Correlation between State's Share of US Patents in an Industry and Its Share in US Exports in that Industry (RCP, RCX); and Correlation between Share of Patents and Share of Value Added (RCP, RCV)

Average over 1988, 1992, 1996, in Descending Order

Description	SIC	RCP, RCX
Precision instruments	38	0.97
Ind.mach,computers	35	0.93
Electronics	36	0.93
Fabricated metals	34	0.84
Rubber	30	0.84
Stone,clay,glass	32	0.81
Transportation equip.	37	0.78
Textiles	22	0.69
Chemicals	28	0.54
Primary metals	33	0.51
Food	20	0.33

Description	SIC	RCP, RCV
Precision instruments	38	0.97
Electronics	36	0.94
Ind.mach,computers	35	0.92
Fabricated metals	34	0.89
Transportation equip.	37	0.86
Rubber	30	0.83
Stone,clay,glass	32	0.79
Chemicals	28	0.74
Primary metals	33	0.66
Food	20	0.66
Textiles	22	0.57

Table 4. Average Variances across States by Sector over 1988-1996*

Description	SIC	Export RCA	Patent RCA	Difference
Food	20	3.151	1.269	1.88
Textiles	22	3.597	2.660	0.94
Primary Metals	33	3.031	0.961	2.07
Chemicals	28	1.393	0.470	0.92
Stone, Clay, Glass	32	1.296	0.466	0.83
Electronics	36	0.953	0.542	0.41
Rubber, Plastics	30	0.638	0.334	0.30
Transportation Equipment	37	0.690	0.323	0.37
Precision Instruments	38	0.591	0.099	0.49
Industrial Machinery, Computers	35	0.397	0.133	0.26
Fabricated Metals	34	0.370	0.145	0.23
Average		1.464	0.67	

*Note: RCP = revealed comparative advantage in patenting, RCX = revealed comparative advantage in exporting. Since sectors with higher RCA index averages will generate higher variances, these figures are weighted by the average index.

Table 5.: Persistence of Technological, Production and Exporting Specialization
Period T1: 1988-90, T2: 1994-96

		$RCAP_{T2} = a + bRCAP_{T1}$			$RCAVA_{T2} = a + bRCAVA_{T1}$			$RCAX_{T2} = a + bRCAX_{T1}$		
Sector	SIC	Est. coeff (s.e.)	Adj R-sq	Is b significantly different from 1 at 10% level?	Est. coeff (s.e.)	Adj R-sq F-stat	Is b significantly different from 1 at 10% level?	Est. coeff (s.e.)	Adj R-sq	Is b significantly different from 1 at 10% level?
Electronics	36	0.9553***	0.70	no	0.8315***	0.49	no	0.7961***	0.82	yes
		(0.0880)	0.26		(0.1294)	1.70		(0.0532)	14.72	
Industrial Machinery, Computers	35	0.8517***	0.67	yes	0.9495***	0.78	no	0.8523***	0.74	yes
		(0.0845)	3.08		(0.0755)	0.45		(0.0720)	4.21	
Instruments	38	0.8120***	0.56	yes	0.7479***	0.69	yes	0.8065***	0.83	yes
		(0.1010)	3.46		(0.0775)	10.60		(0.0522)	13.77	
Chemicals	28	0.8814***	0.89	yes	0.9554***	0.92	no	1.0450***	0.81	no
		(0.0441)	7.24		(0.0436)	1.05		(0.0720)	0.39	
Fabricated Metals	34	0.7547***	0.48	yes	0.8206***	0.69	yes	0.7480***	0.42	yes
		(0.1121)	4.79		(0.0836)	4.61		(0.1237)	4.15	
Transport Equipment	37	0.7044***	0.52	yes	0.7399***	0.57	yes	0.9093***	0.72	no
		(0.0962)	9.44		(0.0995)	6.84		(0.0813)	1.25	
Rubber, Plastics	30	1.0726***	0.55	no	0.6636***	0.70	yes	0.7556***	0.70	yes
		(0.1379)	0.28		(0.0672)	25.06		(0.0709)	11.88	
Stone, Clay, Glass	32	0.4691***	0.23	yes	0.9581***	0.69	no	0.5852***	0.55	yes
		(0.1173)	20.48		(0.0994)	0.18		(0.0756)	30.13	
Food	20	0.5296***	0.21	yes	0.6557***	0.84	yes	0.6980***	0.66	yes
		(0.1430)	10.82		(0.0411)	70.17		(0.0712)	17.98	
Primary Metals	33	0.3541***	0.20	yes	0.7730***	0.85	yes	0.9005***	0.63	no
		(0.0983)	43.18		(0.0534)	18.08		(0.0972)	1.05	
Textiles	22	0.8771***	0.79	yes	0.5096***	0.60	yes	0.7837***	0.93	yes
		(0.0639)	3.69		(0.0795)	38.03		(0.0299)	52.45	
Pooled		0.7383***	0.55	yes	0.6492***	0.66	yes	0.7877***	0.72	yes
		(0.0287)	83.41		(0.0216)	262.88		(0.0208)	104.26	

Notes: Below R-squared, we list the F-statistic from the test of whether the coefficient on the indep var =1
Note: in all regressions standard errors were corrected using White's method; n=50.

Table 6. Estimation Results on the Relationship between the Revealed Comparative Advantage in Production and Patenting

Dependent Variable:		RCAVA		RCAVA	
Independent Variable:		RCAP (t-1)		RCAP (t-2)	
Sector	SIC	Coeff (s.e.)	R-sq	Coeff (s.e.)	R-sq
Electronics	36	1.1969***	0.33	1.2522***	0.36
		(0.1399)		(0.1517)	
Industrial Machinery, Computers	35	1.2446***	0.18	1.0287***	0.14
		(0.3646)		(0.2675)	
Instruments	38	1.7313***	0.30	1.8073***	0.33
		(0.3435)		(0.3428)	
Chemicals	28	0.9774***	0.45	0.9762***	0.44
		(0.1417)		(0.1459)	
Fabricated Metals	34	0.0874	0.01	0.0719	0.00
		(0.1302)		(0.1218)	
Transport Equipment	37	0.1554	0.03	0.1686	0.03
		(0.1358)		(0.1392)	
Rubber, Plastics	30	0.2759*	0.07	0.3171*	0.09
		(0.1586)		(0.1680)	
Stone, Clay, Glass	32	-0.0694	0.00	-0.0330	0.00
		(0.1667)		(0.1491)	
Food	20	0.2884***	0.09	0.3491***	0.15
		(0.0820)		(0.0826)	
Primary Metals	33	0.3141***	0.13	0.3399***	0.17
		(0.0871)		(0.0946)	
Textiles	22	0.9233***	0.52	0.8767***	0.51
		(0.1157)		(0.1171)	
Pooled		0.5850***	0.20	0.5841***	0.22
		(0.0997)		(0.0900)	

Note: in all regressions standard errors were corrected using White's method; the number of observations varies by sector and ranges from 275 to 400 in an industry.

Table 7. Estimation Results on the Relationship between the Revealed Comparative Advantage in Exporting and Patenting

Dependent Variable:		RCAX		RCAX	
Independent Variable:		RCAP (t-1)		RCAP (t-2)	
Sector	SIC	Coeff (s.e.)	R-sq	Coeff (s.e.)	R-sq
Electronics	36	1.4867***	0.49	1.4643***	0.50
		(0.3482)		(0.3319)	
Industrial Machinery, Computers	35	0.4971*	0.06	0.4920*	0.06
		(0.2665)		(0.2630)	
Instruments	38	1.1207***	0.18	1.1003***	0.18
		(0.2537)		(0.2696)	
Chemicals	28	0.9291***	0.20	0.9646***	0.21
		(0.2469)		(0.2597)	
Fabricated Metals	34	-0.0575	0.00	-0.0805	0.00
		(0.1258)		(0.1322)	
Transport Equipment	37	0.1388	0.03	0.1602	0.03
		(0.1149)		(0.1188)	
Rubber, Plastics	30	0.8137***	0.26	0.8528***	0.27
		(0.1800)		(0.2024)	
Stone, Clay, Glass	32	0.2293	0.02	0.1657	0.01
		(0.1901)		(0.1981)	
Food	20	0.5138***	0.08	0.5072**	0.08
		(0.1880)		(0.1929)	
Primary Metals	33	0.5503**	0.08	0.5685**	0.09
		(0.2080)		(0.2669)	
Textiles	22	0.7625***	0.49	0.7318***	0.46
		(0.1523)		(0.1538)	
Pooled		0.5970***	0.15	0.5865***	0.15
		(0.0940)		(0.0961)	

Note: in all regressions standard errors were corrected using White's method; the number of observations varies by sector and ranges from 275 to 400 in an industry.