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Innovation in U.S. metropolitan areas: the role of global connectivity

Kristin Brandl*, Marcelo Cano Kollmann**, Hongryol Cha**, Izzet Darendeli**, T.J. Hannigan**, Ahreum Lee**, Seojin Kim**, Vittoria Giada Scalera[§], Alessandra Perri^, Robert D. Hamilton III**, Ram Mudambi**

** Copenhagen Business School; ** Temple University; [§] Politecnico di Milano; ^ University of Venice, Ca Foscari*

ABSTRACT

Managing and leveraging innovation and knowledge generation are key components of value creation by firms in a globally connected world. In this project we analyze innovative activity in the over a 35-year period (1975-2010) to understand the nature and extent of international connectedness of U.S. knowledge networks. Our analysis parses a comprehensive dataset comprising the population of USPTO patents to extract information on inventor co-location. We use this to generate a knowledge map of inventor networks for each of the top 35 Core-Based Statistical Areas (CBSAs), tracking innovative activity and connectedness across geography and over time. We find that in the 1975-90 period, inventor numbers and growth rates tracked overall population numbers, so that the large population centers (New York, Chicago, Los Angeles and Philadelphia) accounted for the largest shares. However, in the decades between 1990 and 2010, inventor numbers rose most rapidly in West and South, so that by the end of the period the dominant innovative centers of the country were the Silicon Valley CBSAs of San Francisco and San Jose, Austin, Seattle, Portland and San Diego.

INTRODUCTION

Knowledge creation by U.S. firms is vitally important to their global competitiveness. However, multinational enterprises (MNEs) must be viewed as globally distributed innovation networks that absorb, create, and manage geographically dispersed knowledge (Bartlett and Ghoshal, 1989). MNEs create superior value by leveraging intangible assets, such as R&D (Mudambi, 2008), and coordinating out of global centers of knowledge (Lorenzen, 2004). Local and global knowledge sourcing are increasingly becoming complements in the innovation strategies of successful firms (Bathelt et al, 2004). U.S. firms are increasingly relying on foreign markets, especially emerging markets, as sources of competitive advantage in this regard. However, objective metrics calibrating the true extent of these activities are scarce: this is the focus of our research.

Current country level "innovation score" data (EIU, 2009) tend to focus on the location of knowledge-creating activities and ignore linkages. However, as MNEs "fine slice" their global value chain activities and locate them around the world (Mudambi, 2008), the resulting entry of new emerging economy locations into global innovation systems does not necessarily reflect a reduction in the importance of traditional locations like the U.S. In other words, the extent to which U.S. firms remain the linchpins of knowledge networks, are positioned at the center of knowledge flows, and are positioned atop the inventor-assignee dynamic may all reveal leadership roles within global value chains. Developing an understanding of knowledge networks may therefore shed light on what appears to be a shift in the location of activities, but not necessarily a shift in value creation or value appropriation (Dedrick, Kraemer, and Linden, 2009; OECD, 2011).

With this in mind, the *Temple Knowledge Maps Project* aims to analyze the inventor networks of major U.S. metro areas. The project involves examining patent data, specifically inventor co-location, with an eye towards understanding the international connectivity of U.S. innovative activity. Our project uses patents from the U.S. Patent and Trademark Office (USPTO) to generate knowledge maps for the top 35 most populous Core-Based Statistical Areas (CBSAs) designated by the U.S. Office of Management and Budget (OMB). The core research questions relating to knowledge networks that we seek to address are:

a) How different policy, industrial, and firm-specific factors impact the global connectivity of local and regional innovation, and

b) How these factors moderate the production of local knowledge.

Analyzing trends at city-level innovative activity over a 35-year period could bring about findings with powerful implications to both the policymakers and firm managers.

DATA AND METHODS

Patent data from the USPTO affords scholars an opportunity to analyze large tranches of innovation data, including the classification of the invention, the location of inventors, and the ownership of the intellectual property (IP) created in the invention. The challenges involved in the collection of patent data are well documented, and have been alleviated by the creation of publicly accessible databases, such as that of the National Bureau of Economic Research (NBER) (Hall, Jaffe, and Trajtenberg, 2001). More recently, research teams have sought to disambiguate inventor data in an effort to fully map the knowledge creation networks of individuals. One such project is the *Harvard Patent Network Dataverse* (DVN), a product of the Harvard Business School and the Harvard Institute of Quantitative Social Science (Lai, D'Amour, Yu, Sun, and Fleming, 2013). The DNV work draws on both raw data from the USPTO and processed data from the NBER set to create a disambiguated set of patent-inventor observations from 1975 through to 2010 (Lai et al, 2013). While the goal of the DVN work was to be able to trace inventor mobility over time, it does offer scholars the benefit of a parsed and complete set of USPTO patents, covering a 35-year period. The full database contains information on over 9.1 million patent inventors, with a singular data file containing more than 1.3 gigabytes of information (Lai et al, 2013).

While the existence of a publicly available patent data set represents a valuable first step for innovation scholars, there remains the core issue of identifying, extracting, and analyzing important subsets of information. In the case of the *Temple Knowledge Maps Project*, data on *specific* CBSAs are extracted in order to conduct meaningful analyses. This involves building new databases, by matching locations in the DVN patent database with CBSA boundaries as defined by the U.S. OMB. There are numerous location markers in the DVN patent inventor records, and we have used zip codes to identify inventors located in the CBSAs of interest to our study. However, we must be able to identify *all* inventors on a given patent, not just those located in our CBSAs. As a result, we must then match patent numbers to all CBSA-based inventors. This generates a list of patents with at least one inventor located in the CBSA of interest.

The CBSA subset of data is then cross-tabulated to the patent unit of analysis: a step that allows us to analyze the locational network of inventors. For example, the co-inventor network on patent number 8,457,013 reports that 7 inventors are distributed in the Philadelphia and China. A corresponding analysis of the patent's assignee, Metrologic Instruments (based in Blackwood, NJ) shows that R&D is undertaken at firm-owned locations in the U.S. and China. On an aggregate level, our study takes CBSA patents and constructs measures of international inventor connectedness. That is to say, to what degree do inventors based in a particular city collaborate internationally? Taking the location analysis further, we leverage the latitude and longitude coordinates to generate full maps of innovative activity and collaboration in both space and time.

The trajectory of this research allow us to mine the large scale DVN database to identify all CBSA-relevant patents, spanning 35 years. This creates a panel data set of computed measures, such as an inventor geographic dispersion index and the proportion of CBSA patents with *any* connectedness. Furthermore, using the CBSA-level data to generate geographic maps of innovative activity allows us to track the development of innovative clusters over time and identity some of the drivers of collaborative innovation.

PRELIMINARY FINDINGS

In the following section we present an overview of the main trends highlighted by the preliminary analysis of the innovation activities of the top 35 CBSAs. After the description of the distribution and evolution of the US innovative activity, we present a short overview of the innovation trends of the Philadelphia CBSA.

US innovative activity

Figure 1 shows the changing locations of U.S. innovative activity during the period 1975-2010. Through approximately 1990, the data emphasize that population size and inventor numbers were strongly correlated. More specifically, the top four inventing CBSAs were the biggest metros – New York, LA, Chicago and Philadelphia. However from 1990 onwards, there was a sea change and the "Silicon Valley" CBSAs started to play the predominant role among the most innovative U.S. cities. San Jose and San Francisco took off first (1991-92) followed by Boston (1993-94) and Seattle (1999-2000). After this shift, only Los Angeles, of the traditional large metros, was able to maintain some degree of comparability with these new innovative hubs.[1]

The picture is made even clearer by examining the share of total innovative activity in the major innovating CBSAs. In **Figure 2** it is possible to observe that the shares of the big metros like New York, Chicago and Philadelphia fall continuously. Only Los Angeles and Boston are able to maintain a stable share. Meanwhile, the shares of the Silicon Valley CBSAs rise steadily along with those of San Diego, Austin and Seattle. With respect to innovative productivity, Seattle, San Jose, San Francisco and Boston appear to be the most productive US cities in terms of US-based inventors, also showing the highest growing trend.

Even with its large base of innovative activity Silicon Valley is still shows only the 4th fastest growth over the period. **Figure 3** demonstrates that Austin experienced the fastest growth followed by Seattle and Portland. In general, the innovation growth is occurring in the South and West and the highest growth rate in the traditional industrial heartlands of the Midwest and the North is registered by Minneapolis at 11th. Finally, California has the highest number CBSAs showing fast innovation growth (3 of the top 10).

Innovation in the Philadelphia area

Figure 4 highlights the high connectedness of Philadelphia-based patents. In fact, during the 1986-2007 period the percentage of internationally connected patents in the Philadelphia area is consistently higher than the national average. The good news is that Philadelphia-based innovation shows growth trend in terms of connectedness, and the pace is faster than the U.S. one.

Looking at the geographical dispersion of inventors, we see that from 1986 onwards Philadelphia-based patents were much more internationally connected than the U.S.-based patents overall. This finding suggests that the co-inventors of patents with at least one inventor located in Philadelphia area were more geographically distributed than the co-inventors of patents with all non-U.S- or all U.S-based inventors (see **Figure 5**). United Kingdom, Germany and Canada represented the top 3 locations of foreign co-inventors, as shown in **Figure 6**.

[1] The DVN database runs through 2010 and is sorted by application year. This induces "right truncation" in the data, i.e., many patents applied for in 2005 and 2006 have not yet been granted by 2010. This is why the curves slope downwards towards the end of the graphed period.

However, from 2004 onward the number of Chinese co-inventors increased dramatically and, although in the following years the growing trend is not stable, China still maintains its role of major innovative partner of Philadelphia.

A representative example of innovative connectedness between Philadelphia and China is the case of Metrologic Instruments. The company, founded in 1968 by C. Harry Knowles, represents the lion's share of the Philadelphia CBSA connectedness to China (13% of the inventors of its patents is located in China). Metrologic was initially specialized in instructional laser kits, and in 1975 it became the world's first producer of hand-held bar code scanner that today are used in retailing, healthcare, postal services, logistics services, and many other industry verticals. The international expansion of Metrologic drove the company to set up a manufacturing and R&D center in Suzhou, China, in 1998. Ten years later it was acquired by Honeywell and today it possesses 446 patents (3189 inventors) and over 100 pending. Among its "Star Scientists" we include the founder, Carl Harry Knowles (354 patents), Xiaoxun Zhu (208 patents) and Thomas Amundsen (131 patents). Collectively, the first 5 inventors are represented on 95.7% of Metrologic's patents. Removing Knowles (to control for owner-bias), the remaining 4 inventors still account for 72.9% of Metrologic's patents.

Although the good news related to the high geographical dispersion of Philadelphia-based innovation, **Figure 7** points out that the share of Philadelphia-based patents as percentage of U.S. patents presents a negative trend, and from 2000 onwards it fell dramatically under 3% (expect for 2002). In sum, Philadelphia's share of U.S. innovative activity has dropped by half in 35 years. This undesirable path should be probably linked with the considerable reduction of the number of patents in the traditional core industries for the Philadelphia area, such as chemical, drugs and medical. In fact, these manufacturing industries have historically represented the main sources of local innovation and from 2001 they showed a declining path, which is particularly severe in the case of drugs (**Figure 8**).

CONCLUSION

Global connectivity is the key to retaining and enhancing local innovation systems, especially today that MNEs increasingly locate innovative activities worldwide. The globalization of innovation and the strategies adopted by the MNEs to leverage globally distributed knowledge have created an interdependent world, in which "local" and "global" need to coexist. In the local scenario a relatively small number of individuals and firms (e.g., Metrologic) can have a disproportionate effect on a local innovation system. With this in mind, the use of knowledge maps for representing the innovative connections of inventor networks gives us a picture of the dependence and linkages of a location in terms of other locations, industries and individuals.

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Figure 1: Number of inventors of the top 15 CBSAs (sorted by application year, 1975-2006)

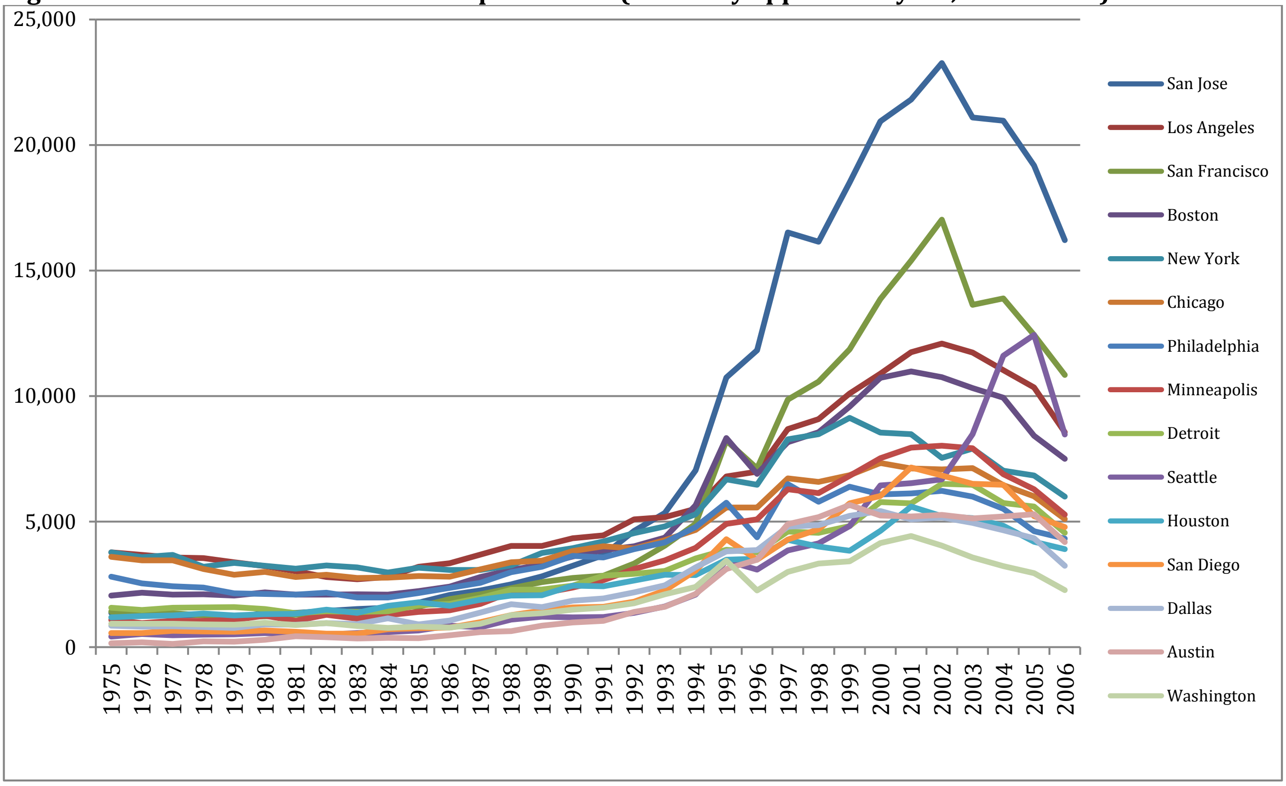

Figure 2: Percentage of US-based inventors of the top 15 CBSAs (sorted by application year, 1975-2006)

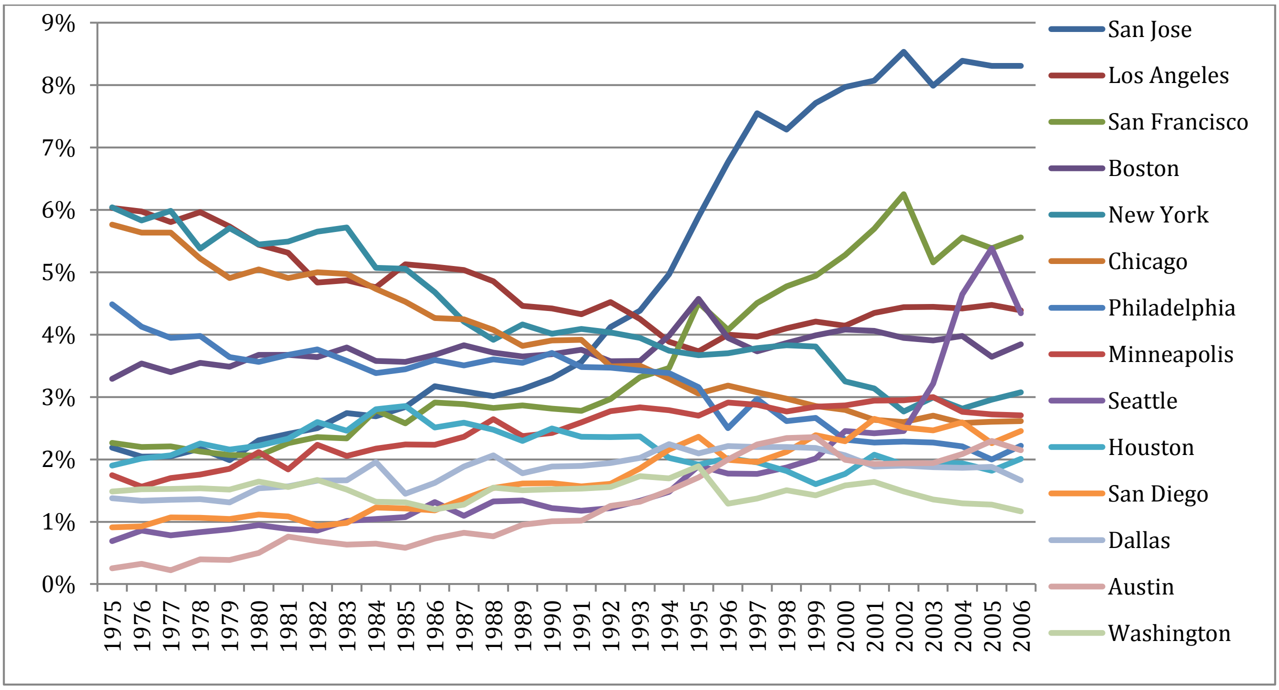

Figure 3: Growth in number of inventors of the top 35 CBSAs (CAGR, sorted by application date, 1975-2005)

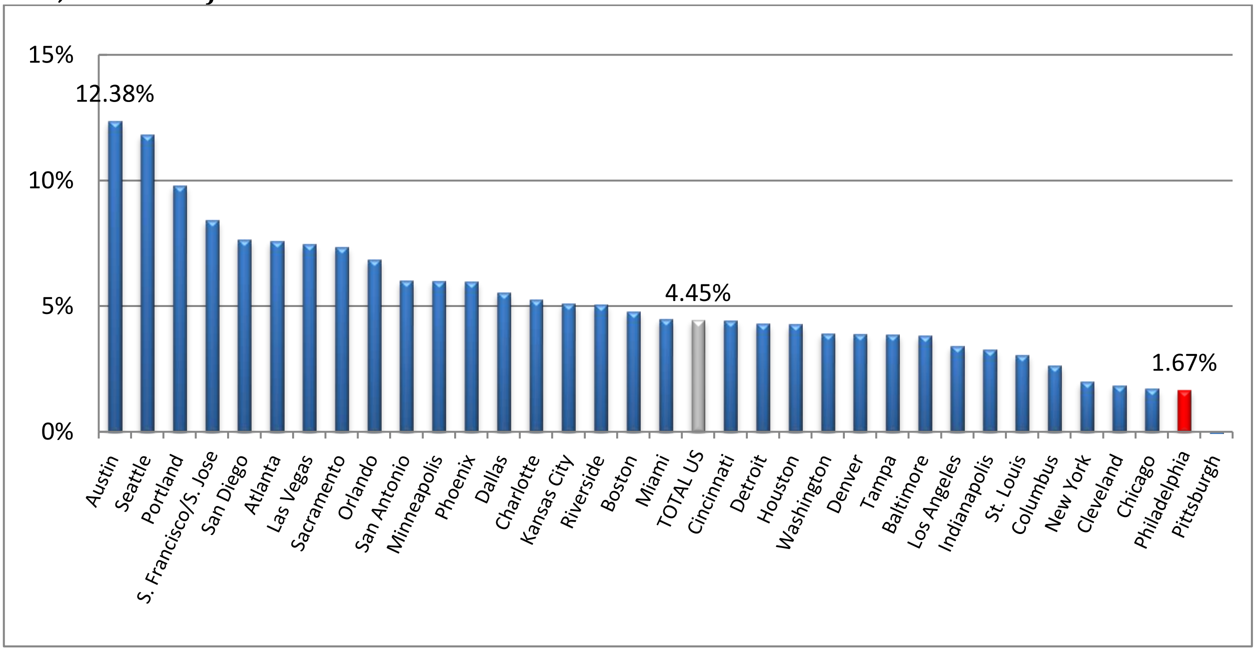

Figure 4: Percentage of internationally connected patents: comparison between US- and Philadelphia-based patents (sorted by application date, 1975 – 2007)

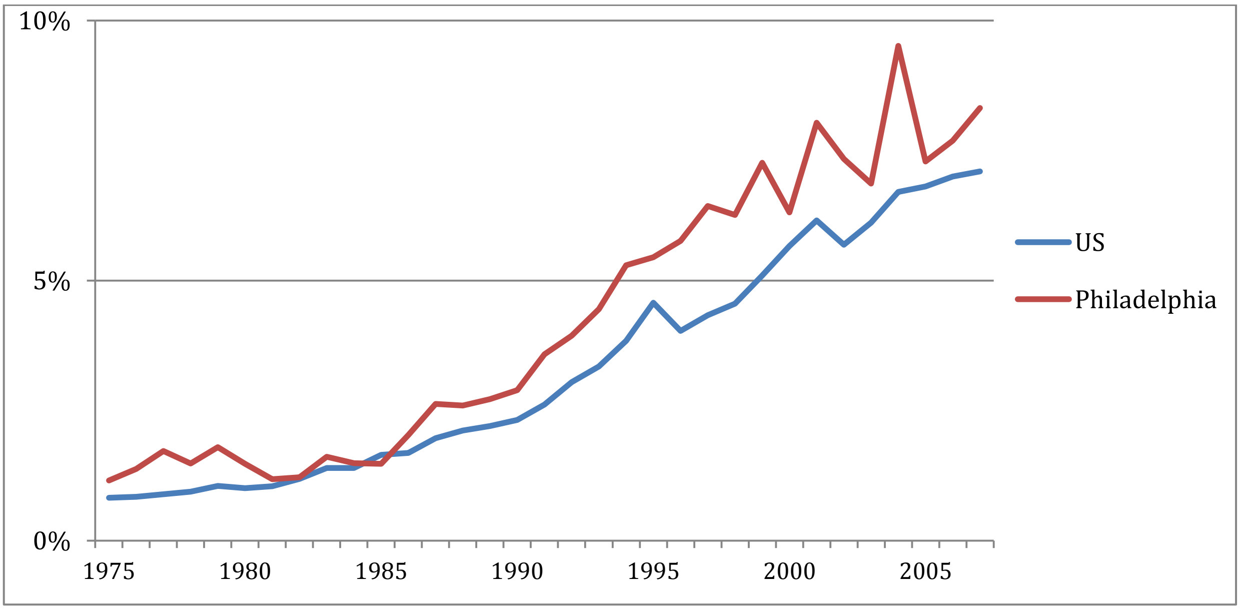

Figure 5: Geographical dispersion of inventors: comparison between US-, Philadelphia- and Non-US-based patents (sorted by application date, 1975-2007)

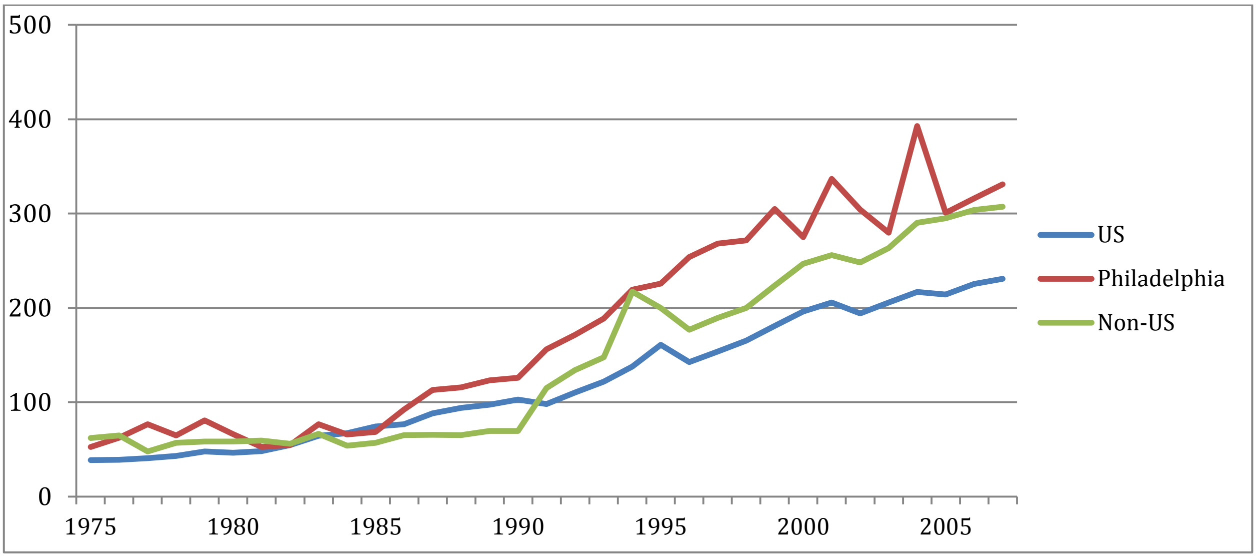

Figure 6: Top 10 locations of Philadelphia-based inventors (sorted by application date, 1975-2007)

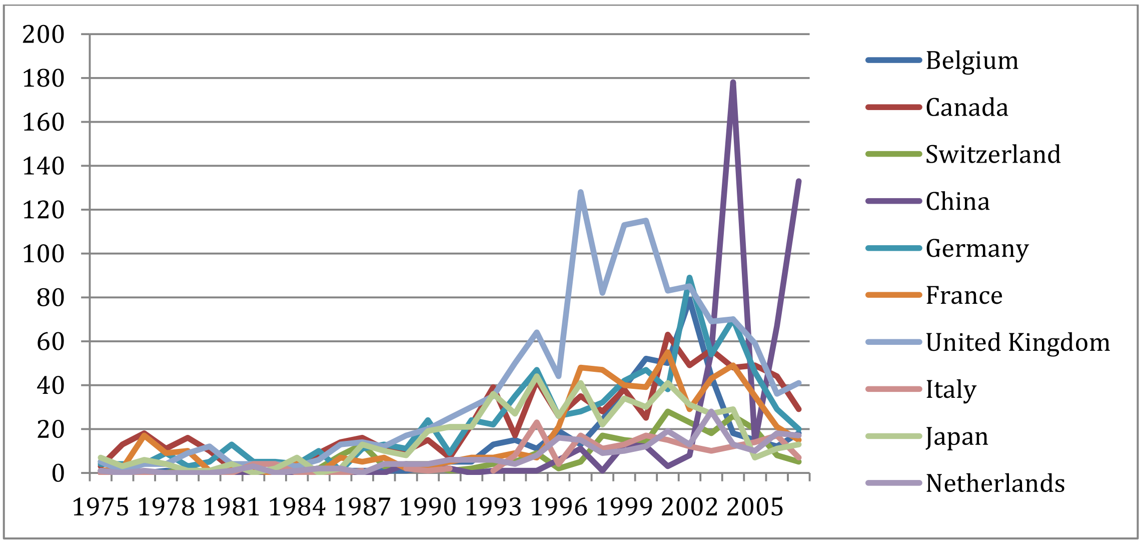

Figure 7: Philadelphia CBSA patents as percentage of US patents (sorted by application date, 1975-2010)

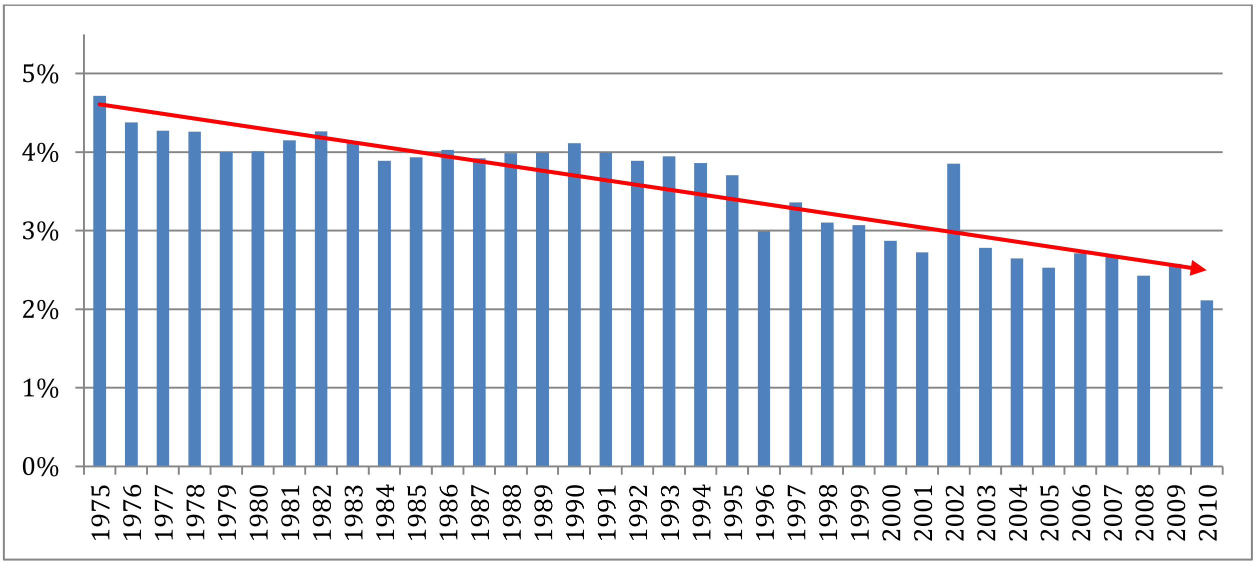

Figure 8: Primary Technology Category of Philadelphia-based patents (sorted by est. grant date, 1978-2008)