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Paper Title

Innovation Clusters: A Study of Patents and Citations

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Innovation Clusters: A Study of Patents and Citations

Abstract:
Patents and citations are considered as variables of innovation and used for studying the flow of knowledge between geographic regions. This study looks into the distribution of patents in Indiana, their inventors, the citations database and how these patents have made citations-to or received citations-from other patents all across the U.S.

The study strives to focus on Indiana and its counties, particularly a 14 county region in north central Indiana known as the WIRED (Workforce Innovation in Regional Economic Development) region, a workforce development program region. Data from several sources, such as United States Patent and Trademark Office (USPTO), National Bureau of Economic Research (NBER), and University of California at Berkeley are explored through GIS to understand the geographic regions of innovation and the flow of knowledge.

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Limitations:
The study uses public sources of data as much as available and proposes to make use of the proprietary data if available and permissible. Purdue Center for Regional Development is preparing a GIS database of patents and citations as available from the National Bureau of Economic Research (NBER), National Science Foundation (NSF), and University of California at Berkeley. This study is part of a continuing in-house GIS database preparation and analysis. While many people have given insights and encouragement, the responsibilities of errors remain with the author.

Introduction:
New economy, knowledge economy, or technology-based economic development are the buzz words in the emerging trends of globalization. Communities are striving to understand their competitive advantages in the rapidly changing economies. Identifying and utilizing innovation potential and knowledge-based assets within a community have gained more importance compared to the traditional economic development approach of focusing on a specific industry sector.

This study looks into innovation as measured by patents and their innovation potential as measured by the citations to do a cross-sectional study of geographies in the U.S. The study uses GIS techniques and the objective is to map the patents and citations for U.S. states and counties, particularly Indiana, which is the focal study area.

Literature Review:

Many researchers have studied patents, citations, inventions, innovations, knowledge-based assets, high-technology occupations to understand their relationships to economic development and growth. They have also studied emerging economic geographies known as the regional innovation system and national innovation system. Many people confer that innovation is an elusive concept however according to Harri Valimaki et al, Joseph Schumpeter was the first economist to define innovation as 1) introduction of a new product or qualitative changes in an existing product, 2) a new method of production, 3) opening of a new market, 4) a discovery of a new input supply, and 5) a change in the industrial structure (Valimaki, Niskanen, Tervonen, Laurila, [6]). Schumpeter and others have defined innovation as a multifaceted activity. Regardless of plenty of research, it is often difficult to measure innovation for lack of good and consistent data. Utility patents are considered as an indicator of innovation and often used as an output indicator to show outcomes of investing on research and development. Similarly, citations of the patents are used to study how valuable the invention is in relation to research and development. Citations are also used to show the technological flow across disciplines.

Several researchers have studied innovation and found evidence of geographic spillovers and spillins. The information and knowledge, which are result of research and development, spillover as neighboring regions benefit from proximity to an innovative region. For example, Anselin et al found that geographic spillovers for university R & D are more compared to private R & D and the R & D in the private sector is dependent on R & D in the universities (Anselin, Varga, and Acs, [1]).

Morino, Paci, and Usai studied *innovation clusters* in European regions and focused on innovations within a sector and if it is affected by specialization and innovations within the same sector or specialization and innovations in the diverse sectors (Morino, Paci, and Usai, [5]). They used patents per 100,000 population as an indicator of innovative activity in the region. Morino et al also pointed out that innovation and knowledge are essential forces for starting and fuelling the *engine of growth*.

Citations are useful in studying the knowledge flow. Based on the industry sector and geographic origin of citing-patents and cited-patents we can study knowledge flow across geographies as well as across the industry sectors. Do knowledge spillovers happen within the industry sector or across the industry sectors? Cooke explored the idea of *knowledge value chains* where firms and institutions engaged in research, exploration, development, and commercialization are increasingly clustering at the regional level, particularly in the life sciences sector (Cooke, [2]). A concept similar to the product value chain or input-output table, knowledge spillovers, sharing and collaborations happen within the knowledge value chains.

Compared to broad coverage of the studies mentioned above, Holmen and Jacobssen looked at one product within a specific technology and build a *knowledge based cluster* around that technology by using the co-classifications and patent citation information. They found that myriad technologies and products were part of the knowledge cluster and these were not related by any means through the traditional value chain based input-output relationships (Holmen and Jacobssen, [4]). Traditional economic development approach identifies industry clusters based on input-output relationships and that could be a limiting factor of this approach in the knowledge based economy.

Existence of innovations such as patents cannot lead to economic development opportunities in a region. Converting innovations into economic ventures require assets such as infrastructure, supportive policies and programs, and institutions. These include university supported technology parks, technology transfer programs, access to venture capital, entrepreneurial programs and spirit. These form the basic ingredients of the technology, knowledge and innovation-based economic development approach. Researchers have studied various social, economic, geographic, political, and other aspects to understand why a region is more innovative compared to the other regions. They have coined terms such as regional innovation system and national innovation system to explain the myriad of conditions required for succeeding in the knowledge economy. However, studying those aspects is beyond the scope of this study.

Methodology:

This study uses spatial analysis techniques to understand distribution of patents per 100,000 population across the U.S. The next part uses citations to understand how patents in a specific field are citing-to and cited-from patents in different fields and different regions. The study specifically looks into the technological category of Drugs and Medical (D & M) developed in a study by the National Bureau of Economic Research (NBER) and University of California at Berkeley (Hall, Jaffe, and Trajtenberg, [3]). The Drugs and Medical (D & M) category is comprised of several classes developed by the U. S. Patents and Trademark Office (USPTO). For Indiana, the following patent classes were found between the grant year 1963 and 2002 (See Table 1). It is assumed that drugs and medical category within patents is an integral part of the biotechnology and biomedical industry cluster. Often communities pursue developing this industry cluster for economic development purposes. The next section shows few examples of GIS analysis and mapping.

Table 1: Patent Classes in Drugs and Medical, Indiana, 1963-2002

Patent Class	Definition
128	Surgery
351	Optics: eye examining, vision testing and correcting
424	Drug: bio-affecting and body treating compositions
433	Dentistry
435	Chemistry: molecular biology and microbiology
514	Drug: bio-affecting and body treating compositions
600	Surgery
601	Surgery: kinesitherapy
602	Surgery: splint, brace, or bandage
604	Surgery
606	Surgery

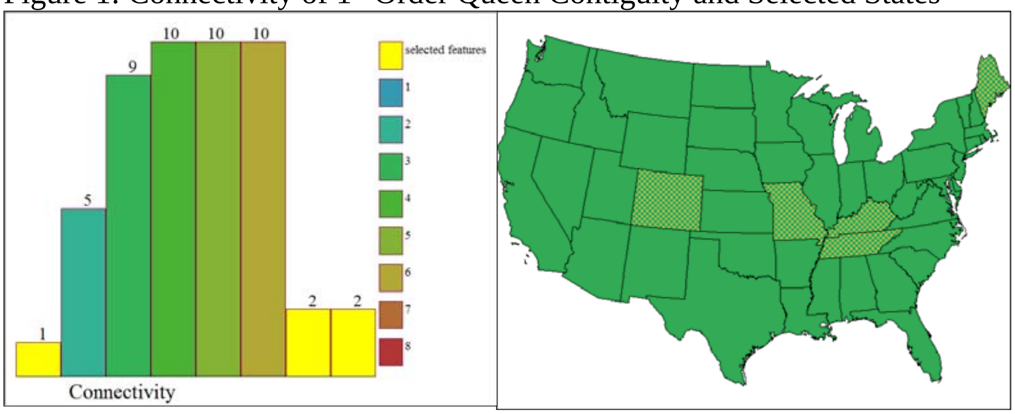
Patent Class	Definition
607	Surgery: light, thermal, and electrical application
623	Prosthesis (i.e., artificial body members), parts thereof, or aids and accessories therefor
800	Multicellular living organisms and unmodified parts thereof and related processes

Source: (Hall, Jaffe, and Trajtenberg, [3])

Exploratory Spatial Data Analysis (ESDA):

This study is comprised of states in the coterminous U.S. with a sample size of 49 states including the District of Columbia. These form a contiguous geographic region without any island. For ESDA, contiguity matrices are needed to show adjacency of the polygon-based data. Here Queen contiguity matrix is selected, which is inclusive of neighbors in all directions. The connectivity of queen first-order weight matrix shows that one state (Maine) has only one neighbor whereas two states (Missouri and Tennessee) have eight neighbors and two more states (Kentucky and Colorado) have seven neighbors each. The states in the Great Plains and Midwest that are central to the spatial system have more number of neighbors (See Figure 1).

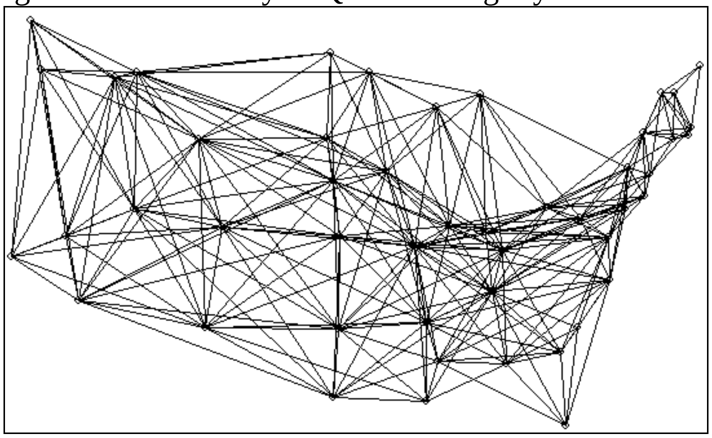
Figure 1: Connectivity of 1st Order Queen Contiguity and Selected States



Source: Author using GeoDa

Spatial connectivity should be studied at various orders of the neighbors. For example, Figure 2 shows a connectivity diagram of the 2nd order Queen Contiguity matrix. This process captures the immediate neighbors as well as the neighbors to those immediate neighbors. Connectivity shows if any geography is detached from the spatial system.

Figure 2: Connectivity of Queen Contiguity 2nd Order Weight Matrix

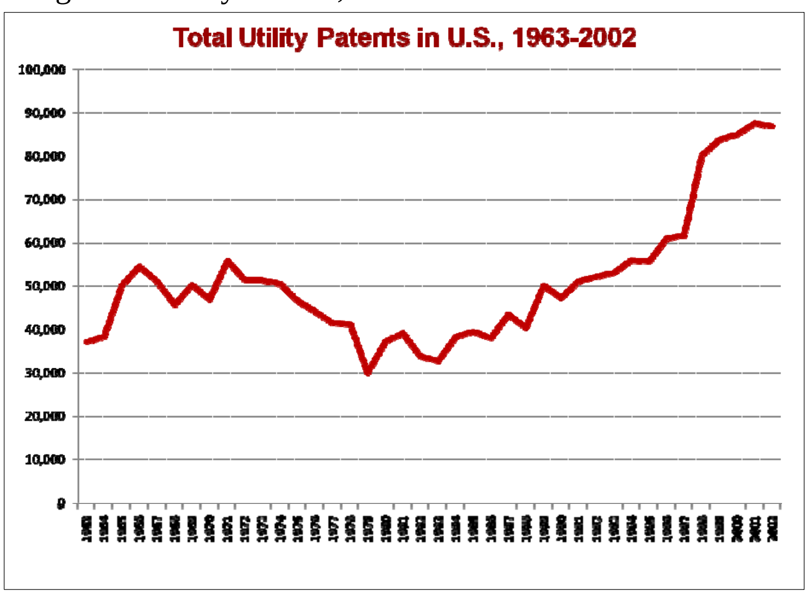


Source: Author using "R"

Trends and Preliminary Results:

The patents granted are constantly increasing with more than 80,000 patents granted every year to U.S. inventors after 2000 (See Figure 3). Since the data is until 2002, current literature mentions that patenting activities have increased recently.

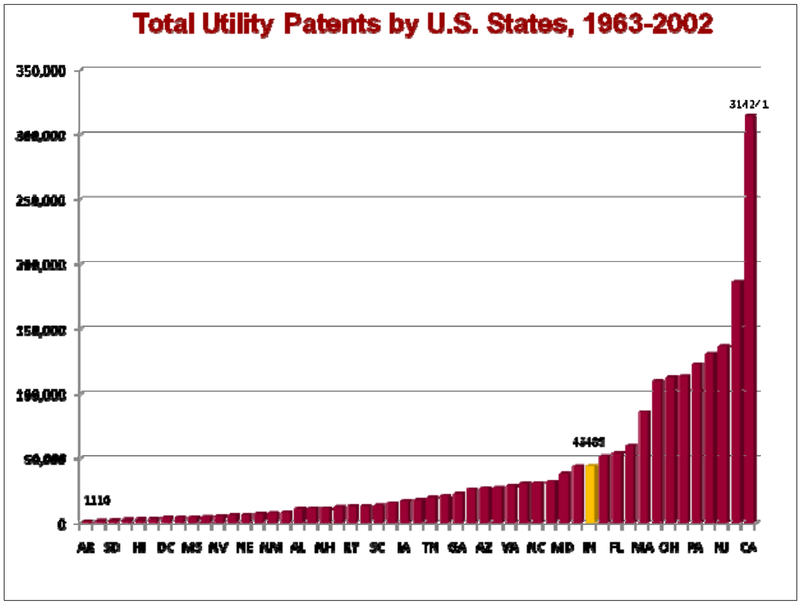
Figure 3: Utility Patents, 1963-2002



Source: NBER, UC Berkeley, (Hall, Jaffe, and Trajtenberg, [3])

The State of Indiana has fared reasonably well in patenting activities. From 1963-2002, California inventors were granted more than 300,000 patents, the maximum than any other state in the U.S. (See Figure 4). During the same period, Indiana inventors were granted more than 40,000 patents with a rank of 13th in the nation.

Figure 4: Utility Patents by State, 1963-2002



Source: NBER, UC Berkeley, (Hall, Jaffe, and Trajtenberg, [3])

Patent counts can be used as an indicator however, patents either normalized by population or employment might give insights on how a state has performed compared to other states. In this case patents per 100,000 population is studied for the most recent year of 2002. California, Texas, New York might exhibit higher number of patents granted in 2002 but by patents per 100,000 population, Idaho is the leading state with 136 granted patents per 100,000 population (See Figures 5 & 6).

Figure 5: Utility Patents by State, 2002

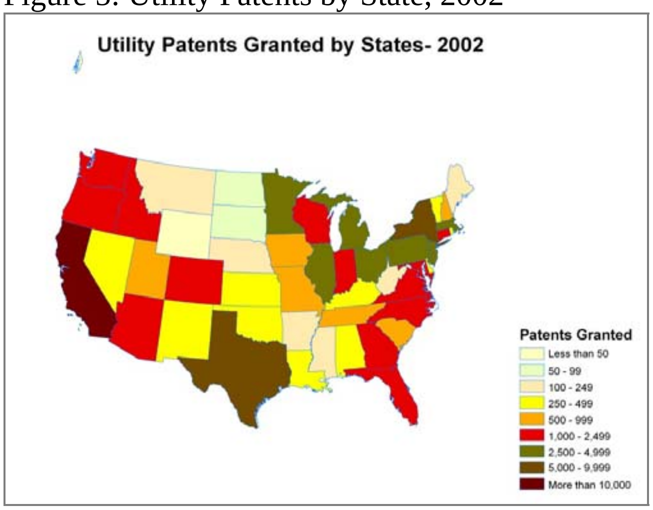
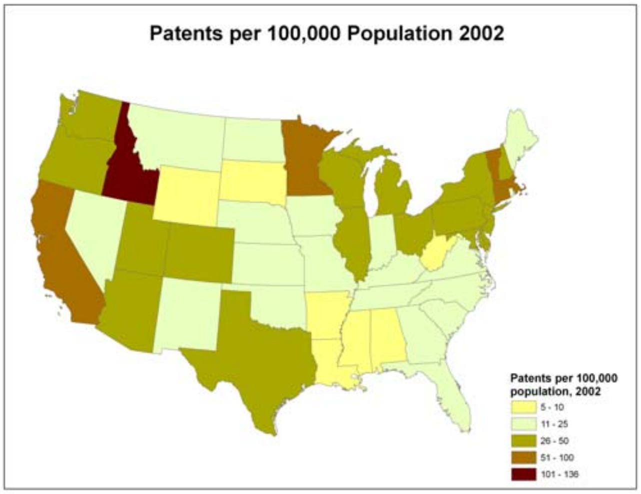


Figure 6: Patents per 100,000 Population by States



Idaho's prominence in the normalized patent counts is exhibited in a cartogram, which adjusts the geographic area based on the numerical value of the indicator. In normal cartography, shape and size of the geography remain constant whereas in a cartogram, they might change. The following map uses ESRI cartogram utility based on Density Equalizing Methodology developed by Mark Newman and Michael Gastner at the University of Michigan (Accessed from www.arcscripts.esri.com). These are also known as anamorphic maps. Other than Idaho, California, Minnesota, Vermont, Massachusetts, Connecticut show higher values in normalized patenting activities as shown by the cartogram (See Figure 7).

The patenting activities by counties might reveal innovative regions within a state. In this case, year 1999 data of inventors available through the NBER is organized by counties by making use of several publicly available state-city-zip code-county databases, such as National Association of Cities and Counties (NACO) and Florida International University. The assignment of inventors for whole of USA to counties is still under progress but a kernel density map of major part of the data reveal concentration of inventors (See Figure 8[1]). It should be noted that USPTO record inventors by residence address and not by their work address and at a county level study, residence vs. work counties might be different. Nevertheless, such kinds of mapping overlaid on metropolitan area and state boundaries might reveal useful insights. Another aspect would be to study temporal changes in the concentration of inventors.

[1] The map is subject to revision following assignment of all the data.

Figure 7: Cartogram, Normalized Patents, 2002

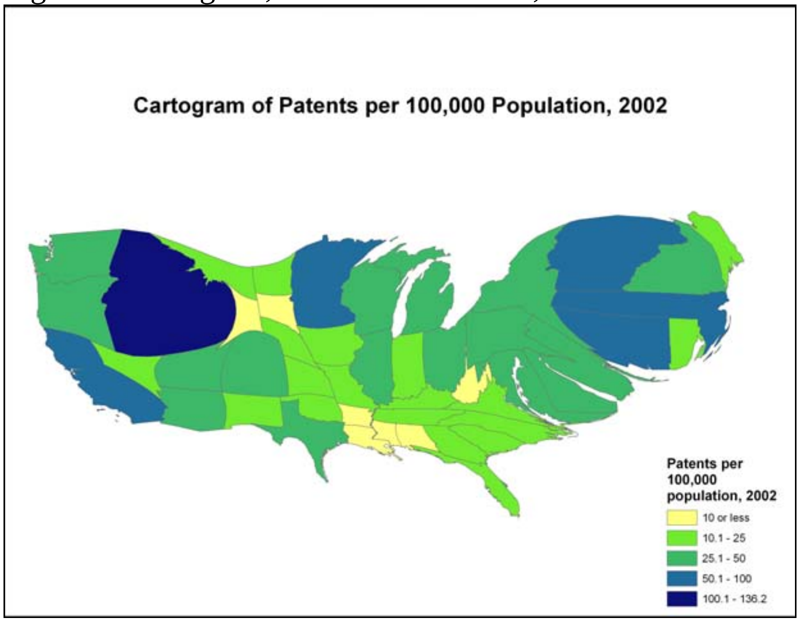
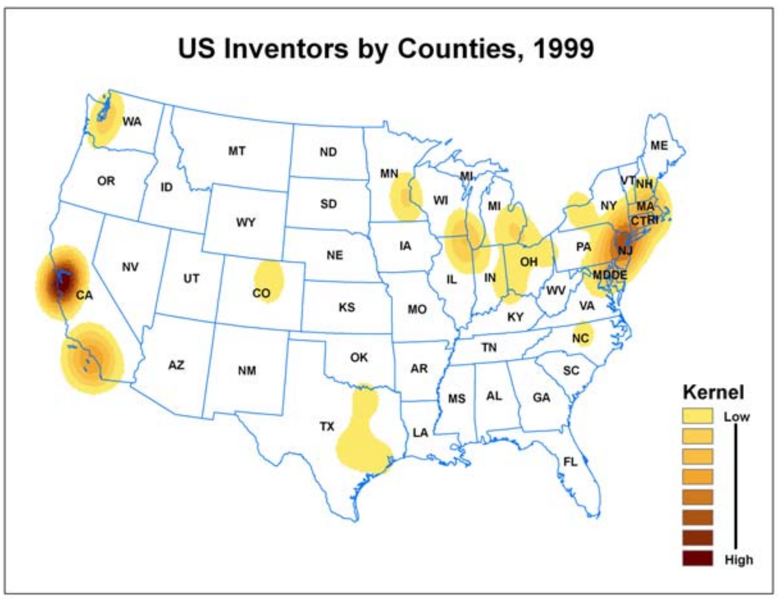
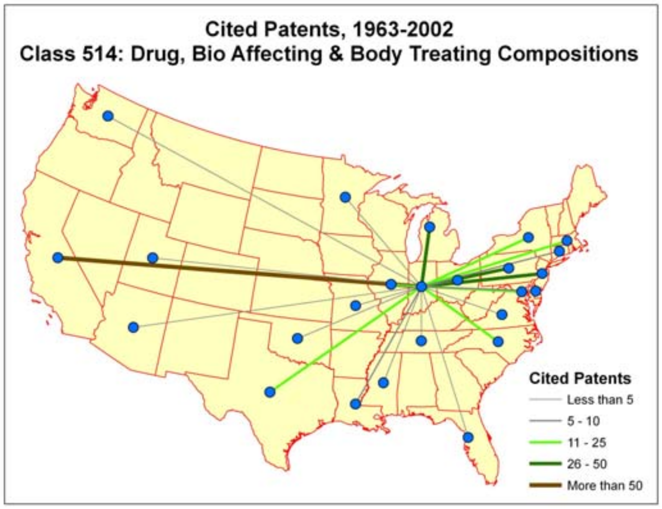


Figure 8: Kernel Density, U.S. Inventors by Counties, 1999



Citations are being studied specifically with respect to Indiana inventions to know how Indiana inventors have been accessing knowledge from different inventions across other states and even other countries. An example of cited patents from one particular patent Class 514, Drug, Bio Affecting and Body Treating Compositions, is shown in Figure 9. Indiana inventors in this particular class have cited patents mainly from California, Pennsylvania, New Jersey, etc. Another interesting aspect is to study these citations over the years to identify prominent regions of inventions in a particular area.

Figure 9: Class 514, Cited Patents



Citation patterns of other patent classes mentioned previously are in progress. Such mapping and analysis could be a useful tool for planning in the new economy.

Note: Figures 5 to 9 are created by the author using ArcGIS program including extensions such as Spatial Analyst, Hawth's Tools, ET GeoWizards, and Spatial Statistics Toolbox.

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