Indiana: Land of Entrepreneurial Opportunity

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Gary S. Becker, the 1992 Nobel laureate from the University of Chicago, wrote recently in *Business Week*: "A successful entrepreneurial environment features continual 'creative destruction,' to use (Austrian economist Joseph) Schumpeter's apt term. New companies prosper and help the economy in part by destroying the markets of established competitors."

In Indiana, there have been recent local and state initiatives to develop a successful entrepreneurial environment. In 1997, Stephen Goldsmith, mayor of Indianapolis, appointed a high tech task force which became the Central Indiana Technology Partnership, in cooperation with the Indianapolis Economic Development Corporation. Goals were to develop a culture to encourage technology-based enterprise, to develop links between innovation sources, to attract technology professionals, and to increase access to financial capital for technology entrepreneurs.

In spring 1999, the Indiana General Assembly appropriated $50 million for a 21st Century Research and Technology Fund. Governor O'Bannon appointed a Board of Directors for the Fund that will allocate the funds to promote high-technology business.

Where does Indiana stand in the development of an entrepreneurial type of environment? This article focuses on patent issuance--one dimension of this type of environment. A patent is an outcome of an information-generating activity involving research and development (R&D) expenditures and efforts of scientific and engineering personnel. Indiana and selected states will be ranked by measures of patent issuance, R&D expenditures, and scientific/engineering personnel. Determinants of the geographic distribution of patent issuance will be identified. This topic is important because clusters of high-technology firms have been shown to generate benefits in terms of employment, income, and economic development. Understanding the determinants of the geography of high-technology firms is important for regional economic policy.

We associate Silicon Valley with an entrepreneurial environment and creative destruction. Can Silicon Valley be transplanted to our Hoosier flatland? The birthplace of Silicon Valley, as designated by the State of California, is an old garage on Addison Avenue in Palo Alto where Hewlett-Packard originated in 1939. Frederick Terman, as Stanford University's dean of engineering and provost, played a critical role during the 1930s in fostering local business-university cooperative relationships based on the model of MIT's department of electrical engineering. His student entrepreneurs included Hewlett, Packard, and Charles Litton. Hewlett-Packard may have been the first university spin-off firm in history. Its growth was stimulated significantly by WWII military contracts--as were other fledging high-tech firms.

In the mid 1960s, a Silicon Valley model was attempted in northern New Jersey (involving Bell Laboratories, RCA's Sarnoff Research Center, Esso Research, Merck, Squibb, Ciba, Union Carbide, and others) but did not take hold. Some observers of high technology initiatives have concluded, "The timing was right," for Silicon Valley, implying that without the military contracts market of WWII and its direct aftermath, it will be a challenge to replicate Silicon Valley elsewhere.[2]

However, the two coastal high-tech concentrations mentioned above continue to be centers of innovative activity today. They have been joined by a variety of state and local initiatives to promote cooperation in research and development between industry and academia. The initiatives include industry-sponsored contract research, long-term university-industry research agreements, and industry-financed university research centers.[3]

Patent Issuance

The process of innovation is common to high-technology firms. Innovation is the commercial application of an invention. This process may be slow and expensive. In biotech, for example, there is the preclinical stage that involves discovery, patent filings, licensing technology, and investigational new drug application. The clinical stage follows and may last 6 to 7 years. The final stage is regulatory approval.

Inventors apply for a patent to protect their intellectual property. As the Biotechnology Industry Organization says, "… patents are among the first and most important benchmarks of progress in developing a new biotechnology product."[4] Thus, patent issuance is used in this study as an indicator of innovative activity.

There are limitations in using patents: 1) many patents never become innovations, and many innovations are never patented; and 2) patents differ in their economic value or impact. To measure temporal and geographic impact, patent citations have been traced. Patents assigned to certain industries, such as electronics, optics, and nuclear technology exhibit high immediate citation but a rapid fading over time due to rapid technological change. University patents tend to generate more citations than corporate which, in turn, generate more than government.

Patent Issuance in Indiana

The issuer of patents is the U.S. Patent and Trademark Office. The residence of the first-named inventor determines the patent origin. **Table 1** lists the top ten organizations in Indiana in terms of number issued from 1994 to 1998.

Individually owned patents not assigned to an organization rank first. A pharmaceutical firm, Eli Lilly, ranks second, more than doubling the next-ranked organization, Delco Electronics. Although these numbers are interesting, they take on more meaning in the broader context of information-generating inputs, such as research and development expenditures, and engineering/scientific personnel considered below.

Patent Issuance by State

How does Indiana rank among states? To compare states, we use a per employee basis, rather than a per capita one, because states differ in their age distributions--some states

Table 1
Patents Issued to Indiana Organizations, 1994 to 1998

Organization	Number issued, 1994-98	Primary locations	
Individually owned patent	902		
Eli Lilly	823	Indianapolis	777
		Lafayette	38
Delco Electronics (Delphi)	313	Kokomo	215
		Indianapolis	69
Thomson Consumer Electronics	260	Indianapolis	256
General Motors	204	Indianapolis	174
General Electric	167	Evansville	91
		Fort Wayne	65
Cummins Engine	143	Columbus	132
Dana Corporation	97	Fort Wayne	79
Zimmer	91	Fort Wayne	25
Purdue Research Foundation	67	West Lafayette	64

Source: U.S. Patent and Trademark Office, Office for Patent and Trademark Information, Technology Assessment and Forecast Program

Table 2
Rank of Patents Per Employee, Patents Issued, and Employment, for Selected States

State	Patents Issued per employee	Patents in 1996	Employment in 1996
Indiana	**22**	**14**	**14**
Illinois	14	5	4
Michigan	9	4	8
Ohio	18	8	7
Kentucky	41	33	26
Wisconsin	20	13	15
California	6	1	1
Massachusetts	4	9	13
New Jersey	5	6	9
Texas	21	3	2

Source: U.S. Patent and Trademark Office and U.S. Department of Labor

have relatively more children than others. **Table 2** ranks states in three ways: by 1996 patents per employee, the number of patents issued in 1996, and total employment in 1996.

California ranks Ist in both the number of patents and employees; that is probably consistent with public perceptions. However, it ranks 6th in patents per employee. Massachusetts ranks higher in patents per employee because its number-of-patents ranking is higher than its employment ranking. Kentucky is lower because of the reverse—a lower patent ranking compared to its employment ranking. Michigan leads the pack in the Midwest. Later in this article, we will identify determinants of these state patterns.

Research and Development Expenditures

R&D expenditures are an input in the generation of patents. Total U.S. expenditures on R&D in 1995 were 183 billion dollars; Indiana's were 3 billion. **Table 3** shows the percent distribution for the U.S. and Indiana of the primary components.

Some of the industry R&D expenditures are from the federal government (14 percent in Indiana, primarily from the Department of Defense). As Table 3 indicates, R&D expenditures may come from industry, the federal government, and universities. Because this study focuses on the spatial distribution of patent issuance at the state level, it is important to note state-level differences. For example, federally funded research and development centers are not uniformly distributed among the states. Note that California has several (see Table 4).

In the Midwest, there are relatively few. In Illinois there are Argonne National Laboratory (University of Chicago) and Fermi National Accelerator Laboratory (Universities Research Association). In Iowa there is Ames Laboratory (Iowa State University). So, Hoosier federal tax dollars exit the state for primarily California, New Mexico, Illinois, Massachusetts, and New York payrolls, buildings, and equipment. On the other hand, Hoosiers are not exposed to the uncertainties (or cutbacks) associated with Congressional funding of these centers.

Industrial Research and Development Expenditures

As **Table 3** indicates, industrial R&E is the largest component of total R&D expenditures. The National Science Foundation has compiled industrial R&D expenditures by 1995 by state. State-level expenditures reflect differences in state industrial structure. For example, the pharmaceutical industry spends a lot. A comparison of states is based on their R&D "intensity:"the ratio of industrial R&D expenditures to gross state product (GSP), a measure of state productive capacity. **Table 5** gives a ranking of research intensity for selected states, and rankings of the two components.

Michigan ranked first in intensity because of its high ranking in industrial R&D compared to its gross state product (GSP). Indiana ranked 15th in GSP, but because it ranked 13th in industrial R&D, its ranking in R&D expenditures per million dollars--moved up and was 12th nationally, and 2nd among the midwestern states listed. California, ranked 1st in both R&D expenditures and GSP--no doubt as publicly perceived, fell to 6th in R&D intensity.

Academic Research and Development Expenditures

Stanford University, and later the University of California at Berkeley and the University of California at San Francisco, played important roles in the development of Silicon Valley. Similarly, the Massachusetts Institute of Technology (MIT) spawned firms locating on Route 128 around Boston. More generally, there is evidence of the role of university research on the spatial concentration of innovative activity.[5] Varga found that there is a "critical mass" of agglomeration required to get the greatest innovative yield from university research spending.[6] The "critical mass" for a local high technology infrastructure was characterized by "…a typical city needs to have a size of around 1 million, its local university enrollment should be about 32,000, and the employment in R&D laboratories, production facilities, and business service firms should be 2,100, 43,000, and 22,000 respectively".[7]

Table 3
Totals and Percent Distribution of R&D Expenditures by Primary Components, U.S. and Indiana, 1995

	Totals		Percent distribution	
Component	U.S. (millions)	Indiana (millions)	U.S.	Indiana
Total R & D	183,045	3,162	100.0	100.0
Industry R & D	129,830	2,721	70.9	86.0
Industry federally funded R&D centers	2,273	0	1.3	0.0
Federal government R & D	17,133	62	9.4	2.0
Universities & colleges R & D	22,406	376	12.2	11.9
University federally funded R&D centers	5,388	0	2.9	0.0
Other nonprofit organizations R&D	5,203	4	3.3	0.1

Source: National Science Foundation, National Patterns of R&D Resources: 1998

It appears that Indianapolis and central Indiana have these characteristics.

One purpose of the Indiana General Assembly's $50 million 21st Century Research and Technology Fund mentioned above is to support efforts to attract academic R&D funding. This funding may come from the private sector or federal agencies such as the National Science Foundation or the National Institutes of Health. In Table 6, states are compared by two measures of R&D intensity similar to industrial R&D intensity in Table 5. The measures differ by source of funding. The Ist focuses on academic funding and is the ratio of academically funded academic R&D per dollar of higher education current-fund expenditures. The 2nd focuses on all sources of academic R&D funding (academic, federal government, and industrial) and is the ratio of academic R&D per dollar of higher education current-fund expenditures.

Table 4
Federally funded Research and Development Centers in California

Center	Administered By	Funded By
Aerospace Corporation	Department of Air Force	Department of Air Force
Arroyo Center	RAND Corporation	Department of Defense, Army
Energy Technology Engineering Center	Rockwell International	Department of Energy
Jet Propulsion Laboratory	California Institute of Technology	NASA
Lawrence Berkeley Laboratory	University of California	Department of Energy
Lawrence Livermore National Laboratory	University of California	Department of Energy
National Defense Research Institute	RAND Corporation	Department of Defense
Project Air Force	RAND Corporation	Department of Defense, Air Force
Stanford Linear Accelerator Center	Stanford University	Department of Energy

Source: National Science Foundation

Table 5
Ranki of R&D Intensity (Industrial R&D/GSP), Industrial R&D, and GSP, 1995, for Selected States

State	R&D intensity	Industrial R&D	GSP
Indiana	**12**	**13**	**15**
Illinois	17	7	4
Kentucky	40	36	26
Michigan	1	2	9
Missouri	18	16	17
Ohio	22	11	7
Wisconsin	25	18	19
California	6	1	1
Massachusetts	3	5	11
New Jersey	8	4	8
Texas	27	6	3

Source: National Science Foundation State Profiles

Table 6
Ranking of Academic R&D Intensity, 1995

State	R&D Intensity (Academically-funded)	R&D Intensity (All Sources--Academic, Federal, Industrial)
Indiana	**24**	**41**
Illinois	31	44
Kentucky	30	48
Michigan	16	19
Missouri	25	28
Ohio	38	40
Wisconsin	26	14
California	32	15
Massachusetts	46	11
New Jersey	10	33
Texas	12	8

Source: National Science Foundation, National Patterns of R&D Resources: 1998

Table 7
Ranking of Scientists and Engineers per 1,000 Employees and Components, 1995, for Selected States

State	Scientists and Engineers per 1,000 Employees	Scientists and Engineers	Employees
Indiana	**44**	**22**	**14**
Illinois	25	6	5
Kentucky	48	33	45
Michigan	31	11	8
Missouri	33	19	16
Ohio	27	9	7
Wisconsin	45	23	15
California	13	1	1
Massachusetts	5	5	13
New Jersey	7	8	9
Texas	34	3	2

Source: U.S. Patent and Trademark Office and U.S. Department of Labor

Each of the midwestern states, with the exception of Wisconsin, has a lower all-sources ranking than academically funded academic R&D ranking. California, Massachusetts, and Texas, on the other hand, have all-sources ranking higher than academically funded academic R&D ranking. This means that the latter states have been able to obtain federal and industrial funding to support their academic R&D to a greater extent than the midwestern states. Indiana is 2nd in the Midwest in academically funded ranking but drops 17 places when the broader funding base is considered. The 21st Century Research and Technology Fund should help to raise Indiana's ranking—although many other states are also appropriating such funds!

Federal Research and Development Expenditures

The federal government defense effort was instrumental in the encouragement of Silicon Valley during WWII and immediately thereafter. In 1995, the primary locations of federal R&D in terms of absolute dollars were Maryland, the District of Columbia, and California. When states are compared in terms of federal R&D expenditures per 1000 doctoral scientists and engineers, Maryland and the District of Columbia continue to rank 1st and 2nd while California falls to 13th because of significant non-federal R&D expenditures. Indiana ranks 37th by this measure.

Scientific and Engineering Personnel

Ideas are embodied in people who have been trained and have developed expertise to pursue technological advance. A recent Eli Lilly expansion announcement includes the hiring of engineers and scientists. The role of "star scientists"--highly productive people who have made a major advancement--has been studied as a means of encouraging scientific development. The focus is on key individuals rather than an average level of human capital/ education. In this article, the focus is on doctoral scientists and engineers. To make interstate comparisons, the number of doctoral scientists and engineers in a state is compared to total state employment--the number of doctoral scientists and engineers per 1,000 employees. **Table 7** provides rankings for selected states by number of scientists and engineers per 1,000 employees.

These rankings reflect differences in states' industrial compositions, the particular function of firms in the state (production sites or corporate headquarters with an R&D component), and the presence of educational institutions. California, Texas, and Massachusetts rank high with a large absolute number of scientists and engineers. As this writer pointed out in an earlier issue of the Indiana Business Review, Indiana does relatively well in training doctoral scientists and engineers (2nd among surrounding Midwest states), but loses them to other states following training; thus our ranking falls.[8]

What determines patent issuance per employee?

Now we use the spatial variation at the state level of the information-generating factors in tables above as a basis for identifying determinants of patents per employee.

We propose the following tentative explanations.

Industrial R&D intensity The higher the industrial R&D intensity, the greater the patents issued per employee.

Academic R&D intensity The higher the academic R&D (funding for academic R&D from academic, federal, and industrial sources) intensity, the greater the patents issued per employee.

Federal government R&D The higher the federal R&D expenditures per 1000 doctoral scientists and engineers, the greater the patents issued per employee.

Educational attainment of persons 25 years and over Educational attainment is measured by the percent of those 25 and over who have completed a bachelor's degree or more. The higher the educational attainment, the greater the patents issued per employee.

Employment density within a state The economics of agglomeration (clustering) suggests that technological spillovers may occur from firms locating next to other firms or universities (the role of Stanford University, University of California at Berkeley and the University of California at San Francisco in Silicon Valley).

The state density index is based on employment per acre in a county compared to other counties in the state.[9] States such as New York, New Jersey, and Massachusettshave the highest density indices while South Dakota, North Dakota, and Montana have the lowest ones. We would expect higher density indices to be associated with higher patents issued per employee.

Empirical results

These tentative explanations are empirically tested via a cross-sectional regression model. The patent data were for 1996; the other variables were for 1995 to suggest a lag between the information generating activity and the patent issuance. Support was strongest for industrial R&D intensity. Also, support was found for educational attainment and academic R&D intensity. The density relationship was as hypothesized but the coefficient was not "statistically significant." On the other hand, federal R&D expenditures relationship had the opposite sign than hypothesized—meaning that higher Federal R&D expenditures per 1000 doctoral scientists and engineers were associated with fewer patents issued per employee. Congressional mandates have encouraged technology transfer at Federal R&D centers. Encouragment includes industrial partnerships, licensing, and spinouts. So, the model "explained" a high degree (63%) of the variation among states in patents per employee.

Conclusions

Patent issuance, as one dimension of innovative activity, has been described in Indiana and other states. The states have been ranked by information-generating activities that are associated with patent issuance. Indiana does relatively well among Midwestern states, especially in industrial R&D intensity which is the primary determinant of patents per employee. For academically funded academic R&D, Indiana is in the middle nationally. However, there is room for improvement when the funding sources of academic R&D are expanded to include industrial and the federal government. In this context, the 21st Century Research and Technology Fund is a step in the right direction.

Higher levels of educational attainment promote patent issuance. Indiana ranked 49th out of 51 (including the District of Columbia) based on the measure used in this study. Much has been written and is being done on raising Indiana's position. We close with two observations and an implication. Research has shown that students who enroll in "gatekeeper" courses, such as algebra and foreign language in eighth grade, are more likely to reach higher levels in high school and to apply to a four-year college than those eighth-grade students who did not.[10] Examining mathematical achievement in eighth grade, Fuchs and Reklis found that characteristics of children (such as readiness to learn in kindergarten) and the mother's education were more important than school characteristics.[11] So as the saying goes, "As the twig is bent, the tree will grow."

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