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Encouraging university entrepreneurship? The effect of the Bayh-Dole Act on university patenting in the United States

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Abstract

Universities are seen as a source of technology development that is useful to entrepreneurial activity. As a result, policy makers often consider mechanisms to stimulate technology commercialization at research universities as a way to encourage entrepreneurial activity in a region. However, the transfer of technology from universities to the private sector requires the exploitation of markets for knowledge, which are fraught with difficulty [Arrow, K., 1962. Economic welfare and the allocation of resources for inventions. In: Nelson, R. (Ed.), *The Rate and Direction of Inventive Activity*. Princeton, NJ: Princeton Univ. Press.]. This article examines the effect of one U.S. public policy initiative—the Bayh-Dole Act in the United States—on one aspect of technology commercialization—university patenting. Specifically, the article explores the university share of patents from 1969 through 1996 across 117 lines of business, and shows that the effectiveness of licensing in a line of business is significantly correlated with university share of patents in the post-Bayh-Dole period, but not in the pre-Bayh-Dole period. These results suggest that the Bayh-Dole Act provided incentives for universities to increase patenting in those fields in which licensing is an effective mechanism for acquiring new technical knowledge. The paper discusses the implications of this shift in patenting for research and public policy.

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1. Executive summary

Universities are often seen as a source of technology development that is useful to economic activity (Mowery et al., 2001; Rosenberg and Nelson, 1994). In fact, evidence of the benefits of university patenting and licensing for economic growth has led many policy makers to consider policies, such as the Bayh-Dole Act, to enhance university technology development and transfer (Henderson et al., 1998; Cohen et al., 1998).

However, previous research has found that Bayh-Dole Act was not responsible for the increase in academic entrepreneurial activity that has occurred in the United States since 1980 (Henderson et al., 1998; Mowery et al., 2001; Mowery and Ziedonis, 2002). Although article does not challenge previous findings about the *aggregate* effects of the Bayh-Dole Act on university patenting, it nevertheless argues that prior research (e.g., Henderson et al., 1998; Mowery et al., 2001) may have missed important *between field* differences in the effect of the Bayh-Dole Act.

Specifically, the article argues that the Bayh-Dole Act led to a shift in university patenting at the margin towards fields in which licensing is an effective mechanism for acquiring new technical knowledge. The Act provided incentives for universities to focus resources on the commercial exploitation of their technology. Because universities exploit their inventions primarily through the licensing of technology, and licensing is not equally effective across all technologies (Levin et al., 1987), the incentive to become more commercially focused led universities to concentrate their patenting in fields in which knowledge is transferred effectively through licensing.

The article explores this argument by examining the university share of patents across 117 lines of business from 1969 to 1996. It shows that the effectiveness of licensing in a line of business is significantly correlated with university share of patents in the post-Bayh-Dole period, but not in the pre-Bayh-Dole period. This effect is robust to controls for the two-digit SIC code in which the line of business is found, the closeness of the line of business to science, and whether the line of business is one in which biomedical inventions are found. The results are also robust to controls for the annual amount of real academic research and development expenditure, the proportion of such funding provided by industry, the proportion used for applied research, and the National Institute of Health's share of federal funding for academic research. Finally, the data do not support two important alternative explanations: (1) after Bayh-Dole, university patenting increased primarily in lines of business in which biomedical inventions are found and (2) after Bayh-Dole, university patenting increased primarily in lines of business that are closer to basic science. Rather, the results suggest that the Bayh-Dole Act led universities to concentrate their patenting in lines of business in which licensing is more effective.

The results have several important implications for research and public policy. First, the results suggest that researchers should reconsider the conclusion that the Bayh-Dole Act has had little effect on university patenting (Mowery et al., 2001). The results here suggest that the Bayh-Dole Act had an important effect on the distribution of university patents across lines of business. Second, the post-Bayh-Dole shift in the focus university patenting has important implications for understanding the conflict between university departments over

technology transfer that has developed in recent years. Third, the results provide evidence for why changes in public policy, such as the Bayh-Dole Act, should be evaluated at the industry level (Levin et al., 1987). Fourth, the results suggest that policy makers in emerging regions think carefully about the incentive effects of policies like the Bayh-Dole Act on university technology production before adopting policies similar to those undertaken in the United States.

2. Introduction

Universities are often seen as a source of technology development that is useful to economic activity (Mowery et al., 2001; Rosenberg and Nelson, 1994). Prior research has shown that commercially oriented university-activity, like patenting and licensing, has been important to the growth of the scientific instrument, semiconductor, computer software, and biotechnology industries (Rosenberg and Nelson, 1994). Moreover, economists have provided quantitative evidence of the beneficial effect on private sector activity of knowledge spillovers from university patenting (Acs et al., 1992, 1994; Jaffe, 1989; Jaffe et al., 1993).

Evidence of the benefits of university patenting and licensing on economic growth has led many policy makers to consider government policies to encourage university technology development and transfer as a way to encourage entrepreneurial activity in a region (Slaughter and Leslie, 1997). This interest, in turn, has led several researchers to consider the effects of government policy on university technology creation and transfer (Henderson et al., 1998; Mowery et al., 2001). In particular, these researchers have examined the effect of the Bayh-Dole Act, which gave U.S. universities property rights to federally funded inventions, on university activity to develop and commercialize technology (Henderson et al., 1998; Mowery et al., 2001).

In general, this research has found that Bayh-Dole Act had little effect on the increase in the university activity to commercialize technology that has occurred since the time of the Act (Henderson et al., 1998; Mowery et al., 2001; Mowery and Ziedonis, 2002). In fact, these researchers have argued that much of the increase in commercially oriented university activities, such as patenting and licensing that has occurred since 1980 was driven by contemporaneous shifts in intellectual property laws and regimes for funding academic research (Henderson et al., 1998; Mowery et al., 2001; Mowery and Ziedonis, 2002).

While this article does not challenge previous findings on the *aggregate* effects of the Bayh-Dole Act on university efforts to commercialize technology, it argues that prior research (e.g., Henderson et al., 1998; Mowery et al., 2001) may have missed important *between field* differences in the effects of the Bayh-Dole Act on university patenting. Specifically, this article argues that the Bayh-Dole Act led to a shift in university patenting at the margin towards fields in which licensing is an effective mechanism for acquiring new technical knowledge. The Act provided incentives for universities to focus resources on the commercial exploitation of their technology. Because universities exploit their inventions primarily through the licensing of technology, and licensing is not equally effective across all technologies (Levin et al., 1987),

the incentive to become more commercially focused led universities to concentrate their patenting in fields in which knowledge is transferred effectively through licensing.

The article explores this argument by examining the university share of patents across 117 lines of business from 1969 to 1996. It shows that the effectiveness of licensing in a line of business is significantly correlated with university share of patents in the post-Bayh-Dole period, but not in the pre-Bayh-Dole period. This effect is robust to the inclusion of controls for the two-digit SIC code in which the line of business is found, the closeness of the line of business to science, and whether the line of business is one in which biomedical inventions are found.¹ The results are also robust to controls for the annual amount of real academic research and development expenditure, the proportion of such funding provided by industry, the proportion used for applied research, and the National Institute of Health's share of federal funding for academic research. Finally, the data do not support two important alternative explanations: (1) after Bayh-Dole, university patenting increased primarily in lines of business in which biomedical inventions are found and (2) after Bayh-Dole, university patenting increased primarily in lines of business that are closer to basic science. Rather, the results suggest that the Bayh-Dole Act led universities to concentrate their patenting in lines of business in which licensing is more effective.

The article proceeds as follows. Section 3 explains why the Bayh-Dole Act led universities to concentrate their patenting in lines of business in which licensing is effective. Section 4 describes the study methodology. Section 5 provides the results. Section 6 discusses the implications of these results for future research and public policy.

3. Markets for knowledge and the licensing of university technology

Organizations have an economic incentive to invest in the development of technical knowledge when they, and not others, can appropriate the economic returns from that knowledge (Arrow, 1962). Private firms can appropriate the returns from the invention of new technology either directly, through the sale of that technology in markets (licensing), or indirectly, through the incorporation of the new technology in products or services that are sold to customers.

Universities differ from private firms in the ways in which they can appropriate private economic returns from the invention of new technology. Universities do not manufacture goods or provide services other than education, making it difficult for them to profit financially from inventions that must be incorporated into products or services before they

¹ As we discuss in Section 4, prior researchers (e.g., Mowery et al., 2001; Henderson et al., 1998) have shown that universities are disproportionately important inventors in biomedical fields. Because other changes that influence the level of inventive activities of universities in biomedical fields are contemporaneous with the Bayh-Dole Act, controlling for the “biomedical effect” is important in examining the influence of the Bayh-Dole Act on university patenting.

can be sold. As a result, universities appropriate the economic returns to invention almost exclusively through licensing.

Industries vary greatly on the effectiveness of licensing. First, markets for knowledge are more effective when patents are effective tools for overcoming disclosure problems. [Arrow \(1962\)](#) observed that buyers are unwilling to purchase knowledge if they cannot verify its value; and sellers are unwilling to disclose the value of knowledge for fear that buyers will not pay once the knowledge is disclosed. This disclosure problem is mitigated if patents protect the property rights of sellers. However, if lead-time, learning curves, or secrecy provide the major means of protecting knowledge in an industry, the disclosure problem persists, making it difficult to sell knowledge in markets.

Second, markets for knowledge are more effective when intellectual property rights can be enforced easily and effectively. A potential buyer has a disincentive to pay for the rights to exploit an invention when intellectual property rights cannot be enforced. Under these circumstances, it is in the best interest of the acquirer to use legal means to obtain the knowledge from the invention without paying for it (e.g., inventing around the technology). Consequently, when intellectual property rights for inventions cannot be enforced easily and effectively, potential buyers have less incentive to license technology (rather than obtain it through other means), undermining markets for knowledge.

Third, markets for knowledge are more effective when knowledge is easily codified ([Arora, 1995](#)). When knowledge is tacit, and not well understood from contracts, patent documents, or published papers, technology transfer requires interpersonal contact ([Levin et al., 1987](#)). The requirement that organizations use interpersonal channels to transfer knowledge raises the cost of knowledge transfer. In many industries, this increase in costs makes mechanisms to transfer knowledge outside of the organization too expensive to be worthwhile ([Teece, 1977](#)).

Because universities cannot easily appropriate returns to their inventions when licensing is an ineffective mechanism for acquiring new technical knowledge, variation across industries in the effectiveness of licensing creates variation across industries in the ability of universities to earn economic returns from invention. This variation in the ability of universities to earn economic returns from invention, in turn, influences their willingness to protect those inventions through patenting.

Patenting imposes a cost that, from an economic perspective, is worth incurring only if the royalties from licensing those patents exceed the average cost of patenting. If licensing is not effective in an industry, the willingness of firms to license university technology is low, the ability of universities to successfully license those patents is limited, and the royalties that universities can charge for access to those inventions are small. Therefore, if universities are motivated to appropriate private economic returns from their inventions, they will have greater incentive to patent in industries in which licensing is more effective.

The Bayh-Dole Act led universities to focus their patenting in fields in which licensing is more effective because the Act led universities to view technology transfer as a commercial activity. The passage of the Bayh-Dole Act, which gave universities the property rights to federally funded inventions, led to a set of fundamental changes in how university

administrators approach technology transfer. Prior to the Bayh-Dole Act, few universities considered licensing and technology transfer to be an important activity (Mowery et al., 2001). Most universities did not track the inventions of their researchers, and few universities applied for patents or conducted licensing (Henderson et al., 1998). In the pre-Bayh-Dole period, patenting in most universities was undertaken largely because it conferred status on inventors. Little thought was given to the potential salability of patents, and most patents remained unlicensed.

However, the Bayh Dole Act increased the number of universities interested in appropriating private returns from their inventions, and, at those universities already interested in licensing technology, increased the emphasis on appropriating private returns from inventions (Henderson et al., 1998). Although several universities (e.g., MIT, Stanford, University of California, and University of Wisconsin) had been active in patenting and licensing for many decades before the Bayh-Dole Act, many universities began to patent only after the passage of the Bayh-Dole Act (Mowery and Ziedonis, 2002).² Moreover, the Bayh-Dole Act led many universities to establish technology transfer offices whose purpose was to market, monitor, and account for the profits from university inventions (Henderson et al., 1998). Even those universities active in patenting and licensing before the passage of the Bayh-Dole Act, responded to the Act by revamping their intellectual property policies, reorganizing their technology transfer offices, and transferring the responsibility for making patenting decisions to those offices (Mowery et al., 2001). Consequently, in the post-Bayh-Dole era technology-licensing officers, who consider the generation of licensing revenue to be an important objective of their work, make patenting decisions (Jensen and Thursby, 2001).

Furthermore, most universities now make patenting decisions that explicitly consider the salability of university inventions (Jensen and Thursby, 2001). For example, in an ethnographic study of the University of Washington technology transfer office, Kaghan (1997) reports that technologies that are most likely to be marketable receive priority in patenting. Hsu and Bernstein (1997) report that the technology licensing offices at MIT and Harvard University make their patenting decisions on historical patterns in the ease of licensing particular technologies. In fact, many universities now apply for patents conditional on the identification of a licensee for the technology (Mowery and Ziedonis, 2002; Jensen and Thursby, 2001).

In sum, by providing universities with the incentive to take a more commercial approach to technology transfer, the Bayh-Dole Act also gave universities an incentive to consider the appropriation of private returns when making patenting decisions. Since universities cannot easily appropriate the returns from their inventions in lines of business in which licensing is ineffective, they have less incentive to patent inventions in those lines of business. Instead, they have an incentive to focus their patenting in those fields in which licensing is effective.

² According to Mowery and Ziedonis (2002), of the 224 universities that issued at least one patent between 1975 and 1992, 81 had no patents issued before Bayh-Dole and only 51 had more than 10 issued patents before Bayh-Dole.

Given the incentive that the Bayh-Dole Act provided for university administrators to view technology transfer as a business activity, one would expect that university patenting in the post-Bayh-Dole era would become more concentrated in lines of business in which inventions can be licensed effectively.

4. Measurement

4.1. Sample

To evaluate the effect of the Bayh-Dole Act on university patenting across different lines of business, I examine the share of patents assigned to universities across 117 lines of business. The analytic approach used here draws upon two important characteristics of patent data. First, since 1969 the United States Patent and Trademark Office (USPTO) has collected data on the assignee of all U.S. patents. The identification of the assignee allows the USPTO to calculate the annual number of patents assigned to universities, and to all assignees, in each three-digit technology class in the U.S. patent classification system. The data on university-assigned and overall patents can be used to construct an annual “university share” of total patents for each three-digit patent class.

The ability to calculate the university share of patents is important because it allows for the measurement of contribution of universities to inventive activity in a technical field,³ while controlling for the relative propensity of inventors to patent in that technology class.⁴

Moreover, the ability to calculate the university share of patents controls for changes in the propensity of inventors to patent over time. Several researchers have observed that the propensity to patent has increased over time (Henderson et al., 1998) in response to governmental efforts to strengthen intellectual property laws (Jaffe, 1999), judicial decisions that have expanded what is patentable (Mowery et al., 2001),⁵ increases in the productivity of the research process (Kortum and Lerner, 1998), and increases in real research and development expenditure (Jaffe, 1999). Measuring university patents as a share of total patents controls for changes in the overall propensity to patent because the forces that led to an increased propensity to patent should increase both the numerator (university patents) and denominator (total patents) of this ratio proportionately.

³ This approach does not consider the importance of universities to invention in fields in which inventions are not patented, most notably software. Software is traditionally protected by copyright, not by patent.

⁴ Classes in which patents are relatively ineffective should have a low number of university patents and a low number of total patents; whereas classes in which patents are relatively effective should have a high number of university patents and a high number of total patents.

⁵ In 1980, in *Diamond v. Chakrabarty*, the Supreme Court upheld the validity of patenting microorganisms, molecules, and other biotechnology inventions. In 1981, in *Diamond v. Dier*, the courts allowed the patenting of software incorporated in manufacturing processes. In 1982, the U.S. government established the Court of Appeals for the First Circuit as the court of last appeal for patent cases; and this court became a strong champion of patent rights. Finally, between 1980 and 1990, Congress passed a number of laws to strengthen intellectual property (Jaffe, 1999).

Second, the U.S. Department of Commerce provides a concordance between the 1972 Standard Industrial Classification (SIC) System and the U.S. Patent Classification (USPC) System. Although there are inherent differences between SIC system and the USPC system, this concordance allows researchers to match three-digit patent classes to the SIC codes for which they are most closely related.

4.2. Yale survey

The paper examines the influence of patent effectiveness on university patenting in a line of business. Such an examination requires access to data on the effectiveness of patents across lines of business, which is not available from government sources. Because that data is available from the Yale Survey on Innovation (Levin et al., 1987), this study makes use of data from that study. In the Yale Survey, Levin et al. (1987) surveyed 650 technology managers in 130 lines of business about innovation and technical change in their line of business, including the effectiveness of patents as a mechanism for protecting new technology products and processes. Serving as line-of-business experts, respondents were asked to answer Likert scale questions about a variety of dimensions of the innovation process in their line of business. These responses were aggregated across respondents in each line of business to create line of business mean scores, which were used for analysis. Because Levin et al. (1987) matched their lines of business to SIC codes, the responses can also be matched to the three-digit patent classes through the use of the USPTO concordance.

Table 1 identifies the lines of business used in the study. Where more than one three-digit patent class concorded with a line of business, I calculated the arithmetic average of all patent-classes that concorded with that line of business to generate the university share of patents for that line of business.

4.3. Dependent variable

The dependent variable in this study is the annual log-odds of the university share of patents from 1969 to 1996 for each of the 117 lines of business for which both patent data and line of business averages from the Yale Survey were available. I examine the log-odds of the university share rather than the actual share because the log-odds of a percentage share is normally distributed, allowing me to analyze the data through pooled cross-sectional time series ordinary least squares regression.

4.4. Independent variables

4.4.1. Two-digit SIC code dummies

Several observers have pointed out that industries differ significantly in both technological opportunity and appropriability, and that these differences might influence the propensity of universities to patent (Klevorick et al., 1995). Previous research has shown that controlling for two-digit SIC codes captures a significant portion of the cross-industry variance in appropriability and technological opportunity (Cohen and Levin, 1989). Therefore, I measure

industry effects with a series of dummy variables for two-digit SIC codes. The two digit SIC codes were: 20 (food and kindred products), 28 (chemicals and allied products), 29 (petroleum and coal products), 30 (rubber and miscellaneous plastics products), 32 (stone, clay, glass, and concrete products), 33 (primary metal industries), 34 (fabricated metal products), 36 (electrical and electronic equipment), 37 (transportation equipment), and 38 (instruments and related products). SIC code 35 (industrial machinery and equipment) was the omitted base case.

4.4.2. Licensing effectiveness

I measure two variables from the Yale Survey on innovation. The first variable measures the effectiveness of licensing as a mechanism of knowledge acquisition. It was constructed as an average of two items from the Yale Survey. The first item, found under the heading: “How effective is each of the following means by which firms in this line of business may acquire technical knowledge of new or improved *production processes* developed by a competitor,” was “license the technology.” The second item, found under the heading: “How effective is each of the following means by which firms in this line of business may acquire technical knowledge of new or improved *products* developed by a competitor,” was “license the technology.” The items were measured on a seven point Likert scale where one equals “not at all effective” and seven equals “very effective.” The Cronbach’s α of the reliability of combining these two items was .911.

4.4.3. Closeness to science

Following Klevorick et al. (1995) and Nelson (1986), I measure the closeness of the line of business to science. Universities should account for a greater proportion of patents in lines of business which are closer to science (more basic) since it is harder to appropriate the returns to basic research than to applied research, and the private sector should under-invest when appropriation is difficult (Arrow, 1962; Nelson, 1959). Closeness to science was measured as the maximum score for the line of business to the question “indicate the relevance of each of the following areas of basic and applied science to technological progress in this line of business over the past 10–15 years” across the set of basic and applied sciences measured in the Yale Survey (biology, chemistry, geology, mathematics, physics, agricultural science, applied math and operations research, computer science, materials science, medical science and metallurgy). The items were measured on a seven-point scale where 1 = *not relevant* and 7 = *very relevant*. This measure has been used to represent the construct of closeness to science in several previous studies (Klevorick et al., 1995).

4.4.4. Biomedical dummy

Several researchers have observed that university patents are much more common in biomedical fields than in other fields (Henderson et al., 1998; Mowery et al., 2001; Mowery and Ziedonis, 2002). To measure the propensity for universities to concentrate their patents in the biomedical area, I develop a dummy variable of 1 for lines of business in which biomedical inventions are found. To develop this dummy, I start with the definition of biomedical patent classes used by Mowery and Ziedonis (2002), who, in turn, based their

Table 1
Lines of business included in the study

Title	SIC codes	Yale study ID
Meat products	2011, 2013	001
Fluid milk	2026	003
Dairy products, except milk	2021, 2022, 2023, 2024	004
Canned specialties	2032	005
Frozen foods	2037, 2038	006
Processed foods and vegetables	2033, 2034, 2035	007
Breakfast cereals	2043	008
Animal feed	2048	010
Grain mill products	2041, 2044, 2045	011
Wet corn milling	2046	012
Bakery products	2051	013
Sugar	2061, 2062, 2063	014
Confectionery products	2065	015
Chocolate and cocoa products	2066	016
Fats and oils	207	018
Malt and malt beverages	2082, 2083	019
Soft drinks and flavorings	2086, 2087	021
Roasted coffee	2095	022
Industrial gasses	2813	039
Inorganic pigments	2816	040
Industrial inorganic chemicals	2812, 2819	041
Plastics materials and resins	2821	042
Synthetic rubber	2822	043
Synthetic fibers	2823, 2824	044
Drugs	283	045
Perfumes, cosmetics and toilet preparations	2844	046
Soaps, detergents and cleaning preparations	2841, 2842, 2843	047
Paints and allied products	285	048
Industrial organic chemicals	286	049
Fertilizers	2873, 2874, 2875	050
Pesticides and agricultural chemicals	2879	051
Explosives	2892	052
Petroleum refining	291	053
Tires and inner tubes	301	054
Plastic products	307	055
Glass and glass products	3229, 323	057
Cement	324	058
Structural clay products	325	059
Pottery and related products	3261, 3264	060
Concrete and related products	3271, 3272, 3273, 3274	061
Gypsum products	3275	062
Abrasive products	3291	063
Asbestos products	3292	064
Mineral wool and related products	3296	065
Steelworks, rolling and finishing	331	066
Iron and steel foundries	332	067
Primary copper smelting and refining	3331	068

Table 1 (continued)

Title	SIC codes	Yale study ID
Primary lead smelting and refining	3332	069
Primary zinc smelting and refining	3333	070
Primary aluminum smelting, refining and rolling	3334, 3353, 3354, 3355	071
Primary smelting and refining of nonferrous metals	3339	072
Secondary smelting and refining of nonferrous metals	334	073
Rolling, drawing and extruding of nonferrous metals	3351, 3356	074
Drawing and insulating of nonferrous wire	3357	075
Nonferrous metal castings	336	076
Metal cans and containers	3411, 3412	077
Cutlery	3421	078
Hand tools	3423, 3425	079
Heating equipment and plumbing fixtures	3431, 3432, 3433	080
Fabricated structural metal	3441	081
Metal doors, sash, frames and trim	3442	082
Fabricated plate work	3443	083
Screw machine products	345	084
Metal forgings	3462, 3463	085
Ordinance and accessories	348	089
Valves and pipe fittings	3494	090
Turbines and turbine generators	3511	091
Internal combustion engines	3519	092
Farm machinery and equipment	3523	093
Construction machinery and equipment	3531	095
Mining machinery and equipment	3532	096
Oilfield machinery and equipment	3533	097
Conveyors and conveying equipment	3535	099
Hoists, industrial cranes and monorail systems	3536	100
Industrial trucks, tractors, trailers and stackers	3537	101
Machine tools, metal cutting types	3541	102
Machine tool accessories and measuring devices	3545	103
Power driven Hand tools	3546	104
Food products machinery	3551	105
Textile machinery	3552	106
Paper industry machinery	3554	108
Printing trades machinery	3555	109
Pumps and pumping equipment	3561	110
Ball and roller bearings	3562	111
Air and gas compressors	3563	112
Blowers and exhaust and ventilation fans	3564	113
Speed changes, industrial and high speed drives and gears	3566	114
Industrial process furnaces and ovens	3567	115
Electronic computing equipment	3573	116
Scales and balances, except laboratory scales and balances	3576	118
Refrigeration and heating equipment	3585	119
Power, distribution and specialty transformers	3612	120
Switchgear and switchboard apparatus	3613	121
Motors, generators and industrial controls	3621, 3622	122

(continued on next page)

Table 1 (continued)

Title	SIC codes	Yale study ID
Electric welding apparatus	3623	123
Household refrigerators and freezers	3632	126
Lighting fixtures and equipment	3645, 3646	128
Radio and TV receiving sets	3651	129
Phonograph records and prerecorded magnetic tape	3652	130
Communications equipment	3661, 3662	131
Electron tubes	3671, 3672, 3673	132
Semiconductors and related devices	3674	133
Primary and storage batteries	3691, 3692	134
Electrical equipment for internal combustion engines	3694	135
Motor vehicles	3711, 3713	136
Motor vehicle parts and accessories	3714	139
Aircraft and parts, except engines	3721, 3728	141
Aircraft engines and engine parts	3724	142
Ship and boat building and repairing	373	143
Railroad equipment	374	144
Complete guided missiles	376	145
Engineering and scientific instruments	381	147
Measuring and controlling devices	382	148
Optical instruments and lenses	383	149
Dental equipment and supplies	3843	150
Surgical and medical instruments, appliances and supplies	3841, 3842	151
Photographic equipment and supplies	3861	153

definition on USPTO reports. I concord these patent classes with lines of business from the Yale survey. All lines of business with which biomedical patent classes concord were coded 1, and all other lines of business were coded zero.⁶

4.4.5. Applied funding

The shift of academic research toward more applied projects over time (Jaffe, 1999) could have led to an increased university share of patents because patenting is more difficult for more basic research than for applied research (Arrow, 1962). To capture this trend, I measure the annual percentage of academic research that is “applied” using the data and the definition from *Science and Engineering Indicators* (NSF, 2000).

4.4.6. Industry funding

The increase in the industry-funded share of university research over time (Henderson et al., 1998) could have led to an increase in the university share of patents because industry is interested in funding research that generates developments that they can appropriate. Given the need to transfer this technology from the university to industry through market

⁶ The following Yale lines of business were coded biomedical lines of business: 45, 46, 47, 49, 50, 51, 54, 55, 116, 118, 120, 121, 134, 135, 147, 148, 149, 150, 151 and 153.

mechanisms, industry funding should increase the tendency to patent inventions. I measure industry funding by examining the annual proportion of university research that is funded by industry using the data and the definition from *Science and Engineering Indicators* (NSF, 2000).

4.4.7. *University R&D*

The increase in the real amount of university research and development expenditure over time (Henderson et al., 1998) could have led to an increase in the university share of patents because the number of patents depends heavily on the magnitude of research and development expenditures (Cohen and Levin, 1989). I measure university research and development expenditure by examining the annual real (1992) dollar value of total university research and development expenditure provided by *Science and Engineering Indicators* (NSF, 2000).

4.4.8. *NIH funding*

“The growth in federal financial support for basic biomedical research in universities that began in the late 1960s. . . [could have] contributed to growth in university patents” over time (Mowery et al., 2001, p. 100). Since Mowery et al. (2001, p. 112) argue that “the surge of inventive activity in the biomedical and biotechnology fields has been building up for some time, as a result. . . of the long-term expansion of federal bio-medical research funding from the National Institutes of Health,” I measure the annual percentage of federally funded research and development expenditure at universities accounted for by the National Institutes of Health using data from *Science and Engineering Indicators* (NSF, 2000).

4.4.9. *Post Bayh-Dole*

I measure the pre- and post-Bayh Dole eras with a dummy variable of one for the years after the implementation of the Bayh-Dole Act: 1981–1996.

5. Empirical results

Universities have dramatically increased their share of patents in post Bayh-Dole period. The NSF (2000) reports that the university share of patents increased from 0.28% of total patents in 1969 to just fewer than 5.0% in 1996. However, the growth in this overall figure masks high variation in the rate of change in the university share of patents across lines of business. The rate of change in the university share of patents from 1969 to 1996 for the 117 lines of business in this study ranged from a *decrease* of 87% to an *increase* of 1648%.

Table 2 provides the descriptive statistics for the variables examined in the regression analysis. Table 3 provides a correlation matrix for the independent variables. The correlation matrix shows relatively high correlations between several of the time-varying independent variables. For example, industry funding as a percentage of university R&D and the NIH percentage of Federal funding are correlated .80 and .92 with the real value of

Table 2
Descriptive statistics ($n = 3276$)

Variable	Mean	S.D.	Min	Max
Food and kindred (SIC20)	0.15	0.36	0.00	1.00
Chemicals and allied (SIC28)	0.12	0.32	0.00	1.00
Petroleum and coal (SIC29)	0.01	0.09	0.00	1.00
Rubber and miscellaneous plastics (SIC30)	0.02	0.13	0.00	1.00
Stone, clay, glass and concrete (SIC32)	0.08	0.27	0.00	1.00
Primary metal (SIC33)	0.09	0.29	0.00	1.00
Fabricated metal (SIC34)	0.09	0.29	0.00	1.00
Industrial machinery (SIC35)	0.21	0.41	0.00	1.00
Electrical and electronic (SIC36)	0.11	0.31	0.00	1.00
Transportation (SIC37)	0.06	0.24	0.00	1.00
Instruments and related (SIC38)	0.05	0.22	0.00	1.00
Licensing effectiveness	4.43	1.23	1.00	7.00
Closeness to science	6.27	0.66	4.00	7.00
Biomedical dummy	0.17	0.38	0.00	1.00
Applied funding (%)	24.49	2.16	18.30	26.80
Industry funding (%)	4.98	1.63	2.70	7.00
University R&D (US\$ million)	12 689.86	4483.05	7878.00	20811.00
NIH funding (%)	48.00	5.00	35.00	55.00
After Bayh-Dole	0.61	0.49	0.00	1.00

university R&D. Similarly, applied funding as a percentage of total funding and NIH funding as a percentage of Federal funding are correlated .84. Furthermore, the real value of university R&D and the NIH percentage of Federal funding in the year are correlated .72. Consequently, I present several regression models in which one or more of the collinear variables was omitted to demonstrate the robustness of the models to the inclusion of the highly correlated variables.

Table 4 provides the results of pooled-cross sectional time series ordinary least squares regressions to predict the log-odds of the university share of patents. Model 1 estimates the base model without inclusion of an interaction term for the effectiveness of licensing and the post-Bayh-Dole period. As model 1 shows, consistent with previous research (Cohen and Levin, 1989), the dummy variables for the two-digit SIC codes have strong and significant effects on the university share of patents. Second, consistent with the arguments of Mowery et al. (2001) and Henderson et al. (1998), the dummy variable for biomedical lines of business has a strong and significant positive effect on the university share of patents. Third, as Jaffe (1999) suggested, the annual proportion of university research devoted to applied projects has a strong and significant positive effect on the university share of patents. Fourth, as Jaffe (1999) and Mowery et al. (2001) have argued, the real dollar value of university research and development expenditure is correlated with the university share of patents.

However, in contrast to the arguments of Klevorick et al. (1995), the closeness of the line of business to science has no significant effect on the university share of patents. Moreover, neither the annual proportion of university research that is industry funded, nor

Table 3
Correlation matrix ($n=3276$)

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	
1. SIC20	1.00																			
2. SIC28	-.16	1.00																		
3. SIC29	-.04	-.03	1.00																	
4. SIC30	-.06	-.05	-.01	1.00																
5. SIC32	-.12	-.11	-.03	-.04	1.00															
6. SIC33	-.14	-.12	-.03	-.04	-.09	1.00														
7. SIC34	-.14	-.12	-.03	-.04	-.09	-.10	1.00													
8. SIC35	-.22	-.19	-.05	-.07	-.15	-.17	-.17	1.00												
9. SIC36	-.15	-.13	-.03	-.05	-.10	-.11	-.11	-.18	1.00											
10. SIC37	-.11	-.09	-.02	-.03	-.07	-.08	-.08	-.13	-.09	1.00										
11. SIC38	-.10	-.09	-.02	-.03	-.07	-.07	-.07	-.12	-.08	-.06	1.00									
12. Licensing	-.05	.18	.12	.02	.20	.14	-.22	-.23	.04	-.08	.07	1.00								
13. Science	-.10	-.00	.03	-.05	-.00	.24	.11	-.09	-.11	-.06	.09	-.05	1.00							
14. Biomed	-.19	.25	-.04	.29	-.13	-.15	-.15	-.13	.13	-.11	.51	.11	.07	1.00						
15. Applied	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.11	1.00					
16. Industry	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.49	1.00				
17. R and D	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.36	.92	1.00			
18. NIH	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.84	.80	.72	1.00		
19. After BD	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.49	.89	.75	.64	1.00	

Table 4
Pooled cross-sectional time series regression to predict the log-odds of the university share of patents ($n = 3276$)

	Model 1		Model 2		Model 3		Model 4	
	β	<i>t</i> -value	β	<i>t</i> -value	β	<i>t</i> -value	β	<i>t</i> -value
Food and kindred	0.47	48.15****	0.47	48.19****	0.47	48.18****	0.47	48.18****
Chemicals and allied	0.26	25.41****	0.26	25.43****	0.26	25.43****	0.26	25.43****
Petroleum and coal	0.15	17.91****	0.15	17.92****	0.15	17.92****	0.15	17.92****
Rubber and miscellaneous plastics	-0.09	9.81****	-0.09	9.81****	-0.09	9.81****	-0.09	9.81****
Stone, clay, glass and concrete	0.03	3.22**	0.03	3.23**	0.03	3.23**	0.03	3.23**
Primary metal	0.08	7.79****	0.08	7.79****	0.08	7.79****	0.08	7.79****
Fabricated metal	0.00	0.52	0.00	0.52	0.00	0.52	0.00	0.52
Electrical and electronic	0.08	8.63****	0.08	8.63****	0.08	8.63****	0.08	8.63****
Transportation	0.08	9.52****	0.08	9.53****	0.08	9.53****	0.08	9.53****
Instruments and related	-0.02	1.50	-0.02	1.50	-0.02	1.50	-0.02	1.50
Licensing effectiveness	-0.01	0.90	-0.03	2.40*	-0.03	2.35*	-0.03	2.37*
Closeness to science	-0.01	0.50	-0.01	0.50	-0.01	0.67	0.00	0.19
Biomedical dummy	0.33	28.35****	0.33	28.37****	0.32	21.08****	0.33	28.37****
Applied funding	0.17	8.77****	0.17	8.77****	0.17	8.77****	0.17	8.77****
Industry funding	-0.01	0.61	-0.02	0.54	-0.02	0.61	-0.02	0.61
University R&D	0.52	21.54****	0.52	21.55****	0.52	21.55****	0.52	21.55****
NIH funding	-0.01	0.00	-0.01	0.00	-0.01	0.01	-0.01	0.01
After Bayh-Dole	0.15	7.56****	0.08	2.32*	0.08	2.34*	0.14	1.71 [†]
Licensing \times After BD	#		0.08	2.42*	0.07	2.35*	0.07	2.38*
Biomed \times After BD	#		#		0.01	0.55	#	
Science \times After BD	#		#		#		-0.06	0.82
Adjusted R^2	0.79		0.79		0.79		0.79	
<i>F</i> -value	699.80****		664.27****		630.94****		631.03****	

	Model 5		Model 6		Model 7		Model 8	
	β	<i>t</i> -value	β	<i>t</i> -value	β	<i>t</i> -value	β	<i>t</i> -value
Food and kindred	0.47	36.98****	0.47	36.97****	0.47	36.97****	0.47	38.71****
Chemicals and allied	0.26	19.51****	0.26	19.51****	0.26	19.51****	0.26	20.43****
Petroleum and coal	0.15	13.75****	0.15	13.75****	0.15	13.75****	0.15	14.39****
Rubber and miscellaneous plastics	−0.09	7.53****	−0.09	7.53****	−0.09	7.53****	−0.09	7.89****
Stone, clay, glass and concrete	0.03	2.47*	0.03	2.47*	0.03	2.47*	0.03	2.58**
Primary metal	0.08	5.97****	0.08	5.97****	0.08	5.97****	0.08	6.25****
Fabricated metal	0.00	0.40	0.00	0.40	0.00	0.40	0.00	0.41
Electrical and electronic	0.08	6.62****	0.08	6.62****	0.08	6.62****	0.08	6.93****
Transportation	0.08	7.37****	0.08	7.36****	0.08	7.36****	0.08	7.66****
Instruments and related	−0.02	1.16	−0.02	1.16	−0.02	1.16	−0.02	1.21
Licensing effectiveness	−0.03	1.86 [†]	−0.03	1.82 [†]	−0.03	1.84 [†]	−0.03	1.93 [†]
Closeness to science	−0.01	0.50	−0.01	0.50	0.00	0.14	−0.01	0.51
Biomedical dummy	0.33	21.77****	0.33	16.17****	0.33	21.76****	0.33	22.79****
Applied funding	#		#		#		0.19	17.73****
Industry funding	#		#		#		#	
University R&D	#		#		#		#	
NIH funding	#		#		#		#	
After Bayh-Dole	0.52	13.52****	0.52	13.51****	0.59	5.44****	0.44	11.80****
Licensing × After BD	0.08	1.89 [†]	0.08	1.84 [†]	0.08	1.86 [†]	0.08	1.97*
Biomed × After BD	#		0.01	0.43	#		#	
Science × After BD	#		#		−0.06	0.61	#	
Adjusted R^2	0.65		0.65		0.65		0.68	
<i>F</i> -value	405.97****		380.52****		380.55****		436.86****	

(continued on next page)

Table 4 (continued)

	Model 9		Model 10		Model 11		Model 12	
	β	<i>t</i> -value	β	<i>t</i> -value	β	<i>t</i> -value	β	<i>t</i> -value
Food and kindred	0.47	44.11****	0.47	45.65****	0.47	42.19****	0.47	38.71****
Chemicals and allied	0.26	23.28****	0.26	24.09****	0.26	22.26****	0.26	20.42****
Petroleum and coal	0.15	16.40****	0.15	16.98****	0.15	15.69****	0.15	14.39****
Rubber and miscellaneous plastics	-0.09	8.98****	-0.09	9.29****	-0.09	8.59****	-0.09	7.88****
Stone, clay, glass and concrete	0.03	2.95**	0.03	3.06**	0.03	2.82**	0.03	2.58****
Primary metal	0.08	7.12****	0.08	7.39****	0.08	6.81****	0.08	6.25****
Fabricated metal	0.00	0.47	0.00	0.49	0.00	0.45	0.00	0.41
Electrical and electronic	0.08	7.90****	0.08	8.18****	0.08	7.56****	0.08	6.93****
Transportation	0.08	8.76****	0.08	9.08****	0.08	8.33****	0.08	7.66****
Instruments and related	-0.02	1.38	-0.02	1.42	-0.02	1.32	-0.02	1.21
Licensing effectiveness	-0.03	2.21*	-0.03	2.30*	-0.03	2.10*	-0.03	1.88 [†]
Closeness to science	-0.01	0.61	-0.01	0.65	-0.01	0.58	-0.01	0.52
Biomedical dummy	0.33	25.97****	0.33	26.87****	0.33	24.84****	0.32	16.94****
Applied funding	#		#		#		0.19	17.73****
Industry funding	0.70	37.14****	#		#		#	
University R&D	#		0.52	41.33****	#		#	
NIH funding	#		#		0.37	31.38****	#	
After Bayh-Dole	-0.09	2.58*	0.13	4.10****	0.29	8.22****	0.44	11.79****
Licensing \times After BD	0.08	2.24*	0.08	2.31*	0.08	2.13*	0.07	1.91 [†]
Biomed \times After BD	#		#		#		0.01	0.44
Science \times After BD	#		#		#		#	
Adjusted R^2	0.75		0.77		0.73		0.68	
F-value	627.76****		686.69****		557.03****		411.07****	

	Model 13		Model 14		Model 15		Model 16	
	β	<i>t</i> -value	β	<i>t</i> -value	β	<i>t</i> -value	β	<i>t</i> -value
Food and kindred	0.47	38.71****	0.47	44.10****	0.47	44.10****	0.47	45.64****
Chemicals and allied	0.26	20.42****	0.26	23.28****	0.26	23.28****	0.26	24.09****
Petroleum and coal	0.15	14.39****	0.15	16.40****	0.15	16.40****	0.15	16.96****
Rubber and miscellaneous plastics	−0.09	7.88****	−0.09	8.98****	−0.09	8.98****	−0.09	9.29****
Stone, clay, glass and concrete	0.03	2.58**	0.03	2.95**	0.03	2.95**	0.03	3.06**
Primary metal	0.08	6.25****	0.08	7.13****	0.08	7.13****	0.08	7.38****
Fabricated metal	0.00	0.41	0.00	0.47	0.00	0.47	0.00	0.49
Electrical and electronic	0.08	6.93****	0.08	7.90****	0.08	7.90****	0.08	8.18****
Transportation	0.08	7.66****	0.08	8.76****	0.08	8.76****	0.08	9.08****
Instruments and related	−0.02	1.21	−0.02	1.38	−0.02	1.38	−0.02	1.42
Licensing effectiveness	−0.03	1.91 [†]	−0.03	2.16*	−0.03	2.18*	−0.03	2.25*
Closeness to science	0.00	0.15	−0.01	0.61	0.00	0.17	−0.01	0.65
Biomedical dummy	0.33	22.79****	0.32	19.29****	0.33	25.96****	0.32	19.97****
Applied funding	0.09	17.73****	#	#	#	#	#	#
Industry funding	#	#	0.70	37.13****	0.70	37.14****	#	#
University R&D	#	#	#	#	#	#	0.52	41.32****
NIH funding	#	#	#	#	#	#	#	#
After Bayh-Dole	0.50	4.88****	−0.09	2.58**	−0.03	0.34	0.13	4.10****
Licensing × After BD	0.08	1.93 [†]	0.07	2.17*	0.08	2.20*	0.07	2.24*
Biomed × After BD	#	#	0.01	0.51	#	#	0.01	0.53
Science × After BD	−0.06	0.64	#	#	−0.06	0.74	#	#
Adjusted R^2	0.68		0.75		0.75		0.77	
<i>F</i> -value	411.11****		590.71		590.78****		646.17****	

(continued on next page)

Table 4 (continued)

	Model 17		Model 18		Model 19	
	β	<i>t</i> -value	β	<i>t</i> -value	β	<i>t</i> -value
Food and kindred	0.47	45.64****	0.47	42.18****	0.47	42.18****
Chemicals and allied	0.26	24.09****	0.26	22.26****	0.26	22.26****
Petroleum and coal	0.15	14.98****	0.15	15.69****	0.15	15.69****
Rubber and miscellaneous plastics	-0.09	9.30****	-0.09	8.59****	-0.09	8.59****
Stone, clay, glass and concrete	0.03	3.06**	0.03	2.82**	0.03	2.82**
Primary metal	0.08	7.38****	0.08	6.82****	0.08	6.82****
Fabricated metal	0.00	0.49	0.00	0.45	0.00	0.45
Electrical and electronic	0.08	8.18****	0.08	7.56****	0.08	7.56****
Transportation	0.08	9.08****	0.08	8.33****	0.08	8.33****
Instruments and related	-0.02	1.42	-0.02	1.32	-0.02	1.32
Licensing effectiveness	-0.03	2.27*	-0.03	2.05*	-0.03	2.07*
Closeness to science	0.00	0.17	-0.01	0.58	0.00	0.17
Biomedical dummy	0.33	26.87****	0.32	18.46****	0.33	24.83****
Applied funding	#		#		#	
Industry funding	#		#		#	
University R&D	0.52	41.33****	#		#	
NIH funding	#		0.37	31.38****	0.33	24.83****
After Bayh-Dole	0.20	2.25*	0.29	8.20****	0.35	3.69****
Licensing \times After BD	0.08	2.27*	0.07	2.06*	0.07	2.09*
Biomed \times After BD	#		0.01	0.48	#	
Science \times After BD	-0.06	0.77	#		-0.06	0.71
Adjusted R^2	.77		.73		.73	
<i>F</i> -value	646.25****		524.16****		524.22****	

Key: # = not included in the regression.

* $P < .05$.

** $P < .01$.

*** $P < .001$.

**** $P < .0001$.

† $P < .10$, two-tailed tests.

the annual NIH share of federal funding have a significant effect on the university share of funding when other time-varying measures are included in the regression analysis.

Model 2 examines the interaction between the effectiveness of patents in a line of business and the post-Bayh-Dole period. The significant positive coefficient on this interaction term suggests that the increase in the university share of patents after the Bayh-Dole Act has occurred largely in lines of business in which licensing is an effective mechanism for acquiring technical knowledge. This result is consistent with the argument that the Bayh-Dole Act led to increased focus of university patenting in lines of business in which licensing is effective because the Act gave universities an incentive to become more commercially oriented.

Although these results show support for the hypothesized argument, an alternative explanation is that universities were well positioned to capture a greater share of patents in biomedical fields that resulted from the strengthening of intellectual property rights in the post-Bayh Dole era, and that the interaction between the post-Bayh Dole dummy and the effectiveness of licensing proxies this effect. For this reason, in Model 3, I examine the interaction of the Bayh-Dole dummy with the biomedical dummy. If universities increased their share of patents because they benefited disproportionately from a strengthening of intellectual property rights in biomedical fields in the post-Bayh-Dole era, then this interaction effect should be positive and significant. Since the interaction between the biomedical dummy and the post Bayh-Dole dummy is not significant, I do not accept this alternative explanation.

Another alternative explanation is that the tested interaction proxies the effect of an omitted interaction between increases in the value of basic science to commercial application and the post Bayh-Dole period. For this reason, in Model 4, I examine the interaction of the Bayh-Dole dummy with the measure of closeness to science. If a rise in the value of basic science to commercial application in the post-Bayh-Dole era explains the shift in the share of university patents across lines of business, then this interaction term should be positive and significant. Because the interaction between closeness to science and the post Bayh-Dole dummy is not significant, I do not accept this alternative explanation.

Because the time-varying variables (proportion applied, industry funding, university share, and proportion NIH) are highly correlated, I have re-run the analysis omitting these variables. Models 5, 6 and 7 re-examine, without these four variables, the results for Models 2, 3 and 4, respectively. Models 8–19 also re-examine Models 2–4, with each model including one of the four highly correlated time-varying variables. The results of these robustness checks confirm the results presented in Models 2–4. Omitting the highly correlated variables led only to changes in the industry funding and proportion NIH variables, suggesting that these variables proxy for university R&D and proportion applied when those variables are omitted. Moreover, the sign, magnitude and significance of the interaction between the effectiveness of licensing and the post Bayh-Dole era, as well as for the other variables, are stable across all the models, suggesting that these results are not artifacts of multicollinearity.

6. Discussion

The effectiveness of licensing in a line of business is significantly correlated with university share of patents in the post-Bayh-Dole period, but not in the pre-Bayh-Dole period. This result is consistent with the argument that the Bayh-Dole Act gave universities an incentive to take a more commercial approach to patenting than they had adopted in the past. Because universities can appropriate the returns to technological invention only if inventions can be transferred through licensing, and licensing is not effective for all technologies (Levin et al., 1987), this policy led universities to shift their patenting at the margin towards technologies in which licensing is more effective.

Although this finding suggests a new conclusion about the effect of the Bayh-Dole Act on university patenting, it is important to note that this study does not differentiate between two alternative explanations for the source of the post-Bayh-Dole increase in the tendency of universities to patent in lines of business in which licensing is effective. The findings are equally consistent with the argument that the Bayh-Dole Act led universities to focus their *research* in fields in which licensing is more effective, and the argument that the Bayh-Dole Act had no effect on university research, but merely influenced the *propensity to patent* inventions that resulted from university research in which licensing is more effective.

It is also important to note that the results of this study are likely measured with error. The “effectiveness of licensing” measure was based on the responses of 650 technology managers who responded to a survey administered in 1983. The responses may have been influenced by the absence of an objective definition of “effectiveness” or by company-specific factors. Moreover, the cross-sectional nature of this survey requires the measure to be treated as time constant even though no empirical evidence has confirmed its intertemporal stability. Furthermore, the USPTO collects data by patent class, not by SIC code. The use of a patent class-SIC code concordance cannot eliminate the fundamental problem of matching patent data to lines of business—that patents can be applied in more than one line of business. Because the USPTO concordance matches patent classes to lines of business imperfectly, and the Yale survey responses are measured with error, the results reported here are imprecise.

Despite these significant limitations, the results of this study have several important implications for research and public policy. First, the results suggest that researchers should reconsider the conclusion that the Bayh-Dole Act has had little effect on university patenting (Mowery et al., 2001). Although the results here do not contradict previous findings about *aggregate* trends in university patenting, they suggest that the Bayh-Dole Act had an important effect on the distribution of university patents across lines of business. This shift in the locus of university patents suggests an important transformation in the role of universities in the U.S. national innovation system that occurred in response to the Bayh-Dole Act. Universities have responded to the incentives of the government to pay attention to potential private returns to their research by redirecting their patenting efforts toward technologies that are effectively transferred through market mechanisms.

Second, the post-Bayh-Dole shift in the focus university patenting has important implications for understanding the conflict between university departments over technology transfer that has developed in recent years. Traditionally, all academics adhered to a norm of open dissemination of ideas for the benefit of the public good. However, the demands of private industry have led norms in fields closely tied to industry to move away from this tradition in the post-Bayh-Dole era (Feller, 1990). Because academics' views about technology transfer and their academic norms are shaped by potential of their research for commercialization (Lee, 1996), the focus of universities on patenting in fields in which licensing is effective in the post-Bayh-Dole era may explain the conflict over technology transfer between academic units that transfer technology routinely and those that do not. Whereas the potential for patenting technology was once distributed across university departments, the focus of patenting in certain fields in the post-Bayh-Dole era has led to a division of academia into departments whose members benefit privately from university technology transfer and departments whose members do not.

Third, the results suggest that the effects of changes in public policy be considered at the industry level (Levin et al., 1987). Appropriate technology policy in one technical field may not be appropriate in another because blunt instruments may have industry-specific effects that are inconsistent with their overall goals (Klevorick et al., 1995). In the specific case examined here, the Bayh-Dole Act appears to have led to a greater university emphasis on patenting in lines of business in which licensing is effective. Since most university inventions are embryonic and require additional development to make them commercially viable (Jensen and Thursby, 2001), patent protection may be important to encourage private firms to invest in the commercialization of university inventions.⁷

However, in the post-Bayh-Dole era, universities are less likely than they used to be to patent in lines of business in which knowledge cannot be transferred effectively through markets. Thus, the Bayh-Dole Act may not have achieved its goal of encouraging private firms to invest in embryonic university technologies in certain fields. Consequently, other policies may be necessary to encourage university patenting and attract investment to embryonic university technology in lines of business in which licensing is ineffective.

Fourth, the results have important implications for public policymakers in emerging regions interested in using U.S. policy toward research universities as an example of how to harness the power of university research to facilitate local entrepreneurial activity. This study shows that the effective design of such policy depends on an understanding of how the private sector obtains and exploits university inventions. Because universities do not directly commercialize their own inventions, the commercial exploitation of university inventions depends heavily on the effectiveness of markets for knowledge. As the results of this study show, this means that policies which give universities the property rights to their inventions will lead universities to focus their patenting efforts in lines of business in which patenting and licensing is more effective. When designing policies to harness

⁷ This, in fact, was the logic behind the passage of the Bayh-Dole Act.

the power of their research universities, policy makers in emerging regions need to keep this tendency in mind.

In short, this study explored the effect of the Bayh-Dole Act on university patenting. The results suggest that the Act led to a shift in university patenting at the margin towards fields in which licensing is effective. Prior research that has focused on aggregate trends in university patenting appears to have missed these between industry differences. Future research and government policy would benefit from considering them.

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