The Bayh-Dole Act of 1980 and University–Industry Technology Transfer: A Model for Other OECD Governments?*

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ABSTRACT. Recent initiatives by a number of OECD governments suggest considerable interest in emulating the Bayh-Dole Act of 1980, a piece of legislation that is widely credited with stimulating significant growth in university–industry technology transfer and research collaboration in the US. We examine the effects of Bayh-Dole on university–industry collaboration and technology transfer in the US, emphasizing the lengthy history of both activities prior to 1980 and noting the extent to which these activities are rooted in the incentives created by the unusual scale and structure (by comparison with Western Europe or Japan) of the US higher education system. Efforts at "emulation" of the Bayh-Dole policy elsewhere in the OECD are likely to have modest success at best without greater attention to the underlying structural differences among the higher education systems of these nations.

Key words: Bayh-Dole, technology transfer, patents

JEL Classification: O340, O380

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1. Introduction

The relationship between academic research and industrial innovation was a central focus of Edwin Mansfield's research agenda. His papers on academic research and industrial innovation (1991, 1995) were important early contributions to the large literature on the economic benefits of US university research. Mansfield found a high social rate of return to investment in academic research performed between 1960s and 1970s, as well as important complementarities and feedbacks between the "basic" and "commercially oriented" research by academic researchers. Mansfield's findings were published near the peak of the "competitiveness debate" of the 1980s and early 1990s within the US over issues such as the alleged failure of US firms to exploit academic research more effectively for commercial advantage. These concerns contributed to the passage of the Bayh-Dole Act of 1980, which sought to facilitate patenting and licensing by US universities of inventions based on federally funded research.

The Bayh-Dole Act was followed by significant growth in patenting and licensing by US universities, and a number of assessments have argued that expansion in these activities enhanced the social returns to publicly funded research academic. Although tenuously anchored in empirical evidence, these assessments and other factors have led governments in many OECD countries to consider policy initiatives that emulate the Bayh-Dole Act. This paper examines the effects of Bayh-Dole on university–industry collaboration and technology

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transfer in the US. There is a long history of such collaboration and technology transfer in the US university system stretching far back into the pre-1980 period, and these activities have been rooted in the incentives created by the unusual scale and structure (by comparison with many Western European nations or Japan) of the US higher education system. Based on this analysis, we argue that efforts at "emulation" of the Bayh-Dole policy elsewhere in the OECD are likely to have modest success at best without greater attention to the underlying structural differences among the higher education systems of these nations.

The global diffusion of these policies illustrates a phenomenon that has received little attention in the literature on innovation policy—the efforts by policymakers to "borrow" policy instruments from other economies and apply these instruments in very different institutional contexts. History, path dependence, and institutional "embeddedness" all make this type of "emulation" very difficult. Nonetheless, such emulation has been especially widespread in the field of technology policy, most notably in the area of collaborative R&D policies.

Our critique of the efforts to emulate the Bayh-Dole Act relies in part on a survey of recent evidence on the characteristics of the university–industry knowledge exchange and technology transfer, discussed in Section 2. We discuss the effects of Bayh-Dole, relying on evidence from the pre- and post-1980 periods, in Section 3. Section 4 provides an overview of efforts of other OECD nations to emulate the Act, and Section 5 concludes.

2. How does academic research influence industrial innovation? A review of recent studies

A number of recent studies based on interviews and surveys of senior industrial managers in industries ranging from pharmaceuticals to electrical equipment have examined the influence of university research on industrial innovation, and thereby provide additional insight into the role of universities within the US national innovation system. All of these studies (Cohen, *et al*., 2002; GUIRR, 1991; Levin *et al*., 1987; Mansfield, 1991) emphasize the significance of interindustry differences in the relationship between university and industrial innovation. The biomedical sector, especially biotechnology and pharmaceuticals, is unusual, in that university research advances affect industrial innovation more significantly and directly in this field than is true of other sectors.

In these other technological and industrial fields, universities occasionally contributed relevant "inventions," but most commercially significant inventions came from nonacademic research. The incremental advances that were the primary focus of the R&D activities of firms in these sectors were almost exclusively the domain of industrial research, design, problem-solving, and development. University research contributed to technological advances by enhancing knowledge of the fundamental physics and chemistry underlying manufacturing processes and product innovation, an area in which training of scientists and engineers figured prominently, and experimental techniques.

The studies by Levin *et al*. (1987) and Cohen *et al*. (2002) summarize industrial R&D managers' views on the relevance to industrial innovation of various fields of university research (Table I summarizes the results discussed in Levin *et al*., 1987). Virtually all of the fields of university research that were rated as "important" or "very important" for their innovative activities by survey respondents in both studies were related to engineering or applied sciences. These fields of US university research frequently developed in close collaboration with industry. Interestingly, with the exception of chemistry, few basic sciences appear on the list of university research fields deemed by industry respondents to be relevant to their innovative activities.

The absence of fields such as physics and mathematics in Table I, however, should not be interpreted as indicating that academic research in these fields does not contribute to technical advance in industry. Instead, these results reflect the fact that the effects on industrial innovation of basic research findings in such areas as physics, mathematics, and the physical sciences are realized only after a considerable lag. Moreover, application of academic research results may require that these advances be incorporated into

TABLE I
The relevance of university science to industrial technology

Science	No. of industries with "relevance" scores ⩾5	⩾6	Selected industries for which the reported "relevance" of university research was large (≥ 6).
Biology	12	3	Animal feed, drugs, processed fruits/vegetables
Chemistry	19	3	Animal feed, meat products, drugs
Geology	0	0	None
Mathematics	5	1	Optical instruments
Physics	4	2	Optical instruments, electronics
Agricultural science	17	7	Pesticides, animal feed, fertilizers, food products
Applied math/operations research	16	2	Meat products, logging/sawmills
Computer science	34	10	Optical instruments, logging/sawmills, paper machinery
Materials science	29	8	Synthetic rubber, nonferrous metals
Medical science	7	3	Surgical/medical instruments, drugs, coffee
Metallurgy	21	6	Nonferrous metals, fabricated metal products
Chemical engineering	19	6	Canned foods, fertilizers, malt beverages
Electrical engineering	22	2	Semiconductors, scientific instruments
Mechanical engineering	28	9	Hand tools, specialized industrial machinery

Source: Data from the Yale Survey on appropriability and Technological Opportunity in Industry. For a description of the survey, see Levin *et al.* (1987).

the applied sciences, such as chemical engineering, electrical engineering and material sciences. The survey results summarized in Cohen *et al.* (2002) indicate that in most industries, university research results play little if any role in triggering new industrial R&D projects; instead, the stimuli originate with customers or from manufacturing operations. Pharmaceuticals is an exception, since university research results in this field often trigger industrial R&D projects.

Cohen *et al.* (2002) further report that the results of "public research" performed in government laboratories and universities were used more frequently by US industrial firms (on average, in 29.3% of industrial R&D projects) than prototypes emerging from these external sources of research (used in an average of 8.3% of industrial R&D projects). A similar portrait of the relative importance of different outputs of university and public-laboratory research emerges from the responses to questions about the importance to industrial R & D of various information channels (Table II). Although pharmaceuticals is unusual in its assignment of considerable importance to patents and license agreements involving universities and public laboratories, respondents from this industry still rated research publications and conferences as a more important source of information. For most industries, patents and licenses involving inventions from university or public laboratories were reported to be of little importance, compared with publications, conferences, informal interaction with university researchers, and consulting.

Data on the use by industrial R&D managers of academic research results are needed for other industrial economies. Nonetheless, the results of these US studies consistently emphasize that the

TABLE II
Importance to industrial R&D of sources of information on public R&D (including university research)

Information source	% rating it as "very important" for industrial R&D
Publications and reports	41.2%
Informal interaction	35.6
Meetings and conferences	35.1
Consulting	31.8
Contract research	20.9
Recent hires	19.6
Cooperative R&D projects	17.9
Patents	17.5
Licenses	9.5
Personnel exchange	5.8

Source: Cohen *et al.* (2002).

relationship between academic research and industrial innovation in the biomedical field differs from that in other knowledge-intensive sectors. In addition, these studies suggest that academic research rarely produces "prototypes" of inventions for development and commercialization by industry—instead, academic research informs the methods and disciplines employed by firms in their R&D facilities. Finally, the channels rated by industrial R&D managers as most important in this complex interaction between academic and industrial innovation rarely include patents and licenses. Perhaps the most striking aspect of these survey and interview results is the fact that they have not informed the design of recent policy initiatives to enhance the contributions of university research to industrial innovation.

3. The Bayh-Dole Act and Academic Patenting in the United States

Origins of the Bayh-Dole Act

Although some US universities were patenting patent faculty inventions as early as the 1920s, few institutions had developed formal patent policies prior to the late 1940s, and many of these policies embodied considerable ambivalence toward patenting. Public universities were more heavily represented in patenting than private universities during the 1925–1945 period, both within the top research universities and more generally. Moreover, many of the public universities active in patenting faculty inventions sought to insulate themselves from this activity by establishing affiliated but legally separate research foundations such as the Wisconsin Alumni Research Foundation to manage their patent portfolios. Other institutions relied on third-party specialists in patent management such as the Research Corporation (Mowery and Sampat, 2001a; 2001b).

The pre-1980 patenting activities of US universities built on research collaborations between university and industrial researchers that spanned many channels of technology and knowledge exchange, including publishing, training of industrial researchers, faculty consulting, and other activities. University–industry collaboration in turn was facilitated by the unusual structure of the US higher education system (especially by comparison with those of other industrial economies) during the 20th century. The US higher education system was significantly larger, included a very heterogeneous collection of institutions (religious and secular, public and private, large and small, etc.), lacked any centralized national administrative control, and encouraged considerable interinstitutional competition for students, faculty, resources, and prestige (see Geiger, 1986, 1993; Trow, 1979, 1991, among other discussions). In addition, the reliance by many public institutions of higher education on "local" (state-level) sources for political and financial support further enhanced their incentives to develop collaborative relationships with regional industrial and agricultural establishments. The structure of the US higher education system thus strengthened incentives for faculty and academic administrators to collaborate in research and other activities with industry (and to do so through channels that included much more than patenting and licensing) long before the Bayh-Dole Act's passage.

The collaboration between university and industrial researchers, combined with the focus of many US university researchers on scientific problems with important industrial, agricultural, or other public applications, meant that a number of US universities patented faculty inventions throughout the 20th century. Nevertheless, despite the adoption by a growing number of universities of formal patent policies by the 1950s, many of these policies, especially those at medical schools, prohibited patenting of inventions, and university patenting was far less widespread than was true of the post-1980 period. Moreover, many universities chose not to manage patenting and licensing themselves. The Research Corporation, founded in 1912 by Frederick Cottrell, a University of California faculty inventor who wished to use the licensing revenues from his patents to support scientific research, assumed a prominent role as a manager of university patents and licensing. Even in these early decades of patenting and licensing, however, biomedical technologies accounted for a disproportionate share of licensing revenues for

the Research Corporation and other early university licensors, such as the Wisconsin Alumni Research Foundation (Mowery and Sampat, 2001b).

The decade of the 1970s, as much as or more so than the 1980s, represented a watershed in the growth of US university patenting and licensing. US universities expanded their patenting, especially in biomedical fields, and assumed a more prominent role in managing their patenting and licensing activities, supplanting the Research Corporation. Agreements between individual federal agencies and universities also contributed to the expansion of patenting during the 1970s. Private universities in particular began to expand their patenting and licensing rapidly during this decade. The number of universities establishing technology transfer offices and/or hiring technology transfer officers began to grow in the late 1960s, well before the passage of the Bayh-Dole Act. Although the Act was followed by a wave of entry by universities into management of patenting and licensing, growth in these activities was apparent by the late 1970s. Indeed, lobbying by US research universities was one of several factors behind the passage of the Bayh-Dole Act in 1980. The Act therefore is as much an effect as a cause of expanded patenting and licensing by US universities during the post-1960 period.

The Bayh-Dole Patent and Trademark Amendments Act of 1980 provided blanket permission for performers of federally funded research to file for patents on the results of such research and to grant licenses for these patents, including exclusive licenses, to other parties. The Act facilitated university patenting and licensing in at least two ways. First, it replaced a web of Institutional Patent Agreements (IPAs) that had been negotiated between individual universities and federal agencies with a uniform policy. Second, the Act's provisions expressed Congressional support for the negotiation of exclusive licenses between universities and industrial firms for the results of federally funded research.

Supporters of Bayh-Dole asserted that university contributions to innovation were limited by difficulties in patenting the outputs of federally funded research and licensing the patents exclusively to industry. This argument was particularly salient during the competitiveness crisis in the US during the 1970s, in spite of the failure of proponents of Bayh-Dole to offer much evidence in its support (see Eisenberg, 1996; Mowery *et al.*, 2004). Moreover, the Bayh-Dole debates included no discussion of any potentially negative effects of increased patenting and licensing on the other channels through which universities contribute to innovation and economic growth.

The passage of the Bayh-Dole Act was one part of a broader shift in US policy toward stronger intellectual property rights.[1] Among the most important of these policy initiatives was the establishment of the Court of Appeals for the Federal Circuit (CAFC) in 1982. Established to serve as the court of final appeal for patent cases throughout the federal judiciary, the CAFC soon emerged as a strong champion of patentholder rights.[2] But even before the establishment of the CAFC, the 1980 US Supreme Court decision in *Diamond* versus *Chakrabarty* upheld the validity of a broad patent in the new industry of biotechnology, facilitating the patenting and licensing of inventions in this sector. The origins of Bayh-Dole thus must be viewed in the context of this larger shift in US policy toward intellectual property rights.

A number of scholars have documented the role of Bayh-Dole in the growth of patenting and licensing by universities since 1980 (Henderson *et al.*, 1998). But Bayh-Dole is properly viewed as initiating the latest, rather than the first, phase in the history of US university patenting. And this latest phase is characterized by a higher level of direct involvement by universities in management of their patenting and licensing activities, in contrast to the reluctance of many US universities to become directly involved in patenting prior to the 1970s. Public universities were more active in patenting than private institutions during much of the pre-Bayh-Dole era, reflecting the strong incentives that they faced to reap the benefits of university research for local taxpayers and the importance of applied research at many of these institutions. By the 1970s, however, both public and private universities had become directly involved in patenting.

The effects of Bayh-Dole

How did the Bayh-Dole Act affect patenting by US universities? Since overall patenting in the US grew during this period, indicators of university patenting need to be normalized by overall trends in patenting and R&D spending. Figures 1 and 2 present two such indicators that span the period before and after the Bayh-Dole Act. Figure 1 depicts US research university patenting as a share of domestically assigned US patents during 1963–1999, in order to remove the effects of increased patenting in the US by foreign firms and inventors during the late 20th century. Universities increased their share of patenting from less than 0.3% in 1963 to nearly 4% by 1999, but the rate of growth in this share begins to accelerate before rather than after 1980. Figure 2 plots the ratio of aggregate university patenting at time t to aggregate academic R&D expenditures at time $t-1$, for application years 1963–1993.[3] The Figure reveals an increase in aggregate university "patent propensity" after 1981 (as pointed out by Henderson *et al.*, 1998), but this is the continuation of a trend that dates at least as far back as the early 1970s; there is no evidence of a "structural break" in trends in patent propensity after Bayh-Dole.[4]

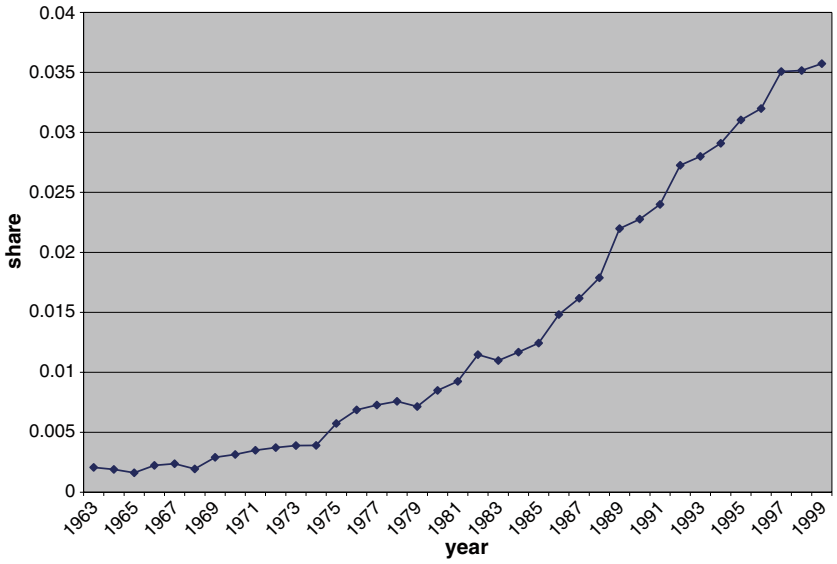

Figure 1. US research univ. patents % of all domestic-assignee US patents, 1963–1999.

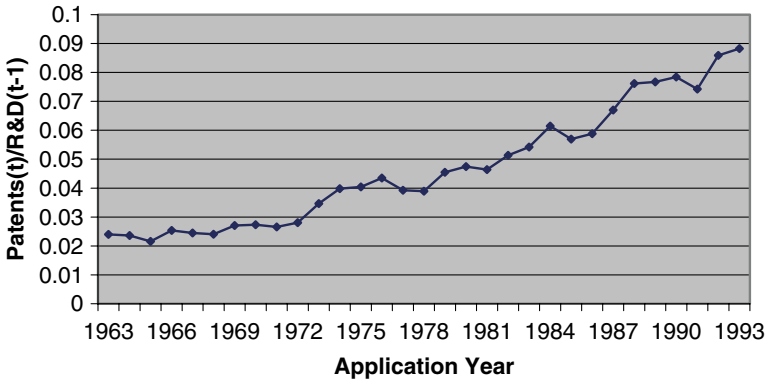

Figure 2. University patents per R&D Dollar, 1963–1993.

Another issue of interest in academic patenting is the distribution among technology fields of university patents during the pre- and post-Bayh-Dole periods. Figure 3 displays this information for US research university patents during 1960–1999, and highlights the growing importance of biomedical patents in the patenting activities of the leading US universities during the period. Non-biomedical university patents increased by 90% from the 1968–1970 period to the 1978–1980 period, but biomedical university patents increased by 295%. This rapid growth in biomedical patents also reflected growth of the IPA program of the major biomedical funding agency (HEW) during the 1970s. The increased share of biomedical disciplines within overall federal academic R&D funding, the dramatic advances in biomedical science that occurred during the 1960s and 1970s, and the strong industrial interest in the results of this biomedical research, all affected the growth of university patenting during this period.

After Bayh-Dole, universities increased their involvement in managing patenting and licensing, setting up internal technology transfer offices to manage licensure of university patents. Figure 4 shows the distribution of years of "entry" by universities into patenting and licensing, defined as the year in which the universities first devoted 0.5 FTE employees to "technology transfer activities" (AUTM, 1998). Although "entry" accelerated after Bayh-Dole, growth in this measure of university commitment to "technology transfer" predates Bayh-Dole. Longitudinal data on university licensing activities are less complete, but the available data indicate that in FY2000, US universities signed more than 4000 license agreements, representing more than a doubling since FY1991 (AUTM, 2000).

Based on these trends in university patenting and licensing, many observers have argued that Bayh-Dole was a major catalyst to university–industry technology transfer. During the late 1990s and early 21st century, many commentators and policymakers portrayed the Bayh-Dole Act as the critical catalyst to growth in US universities' innovative and economic contributions. Indeed, the OECD went so far as to argue that the Bayh-Dole Act was an important factor in the remarkable growth of incomes, employment, and productivity in the US economy of the late 1990s.[5] Implicit in many if not all of these characterizations is the argument that university patenting and licensing in particular were necessary to these asserted increases in the economic contributions of US university research.[6] Similar characterizations of the effects of the Bayh-Dole Act have been articulated by the President of the

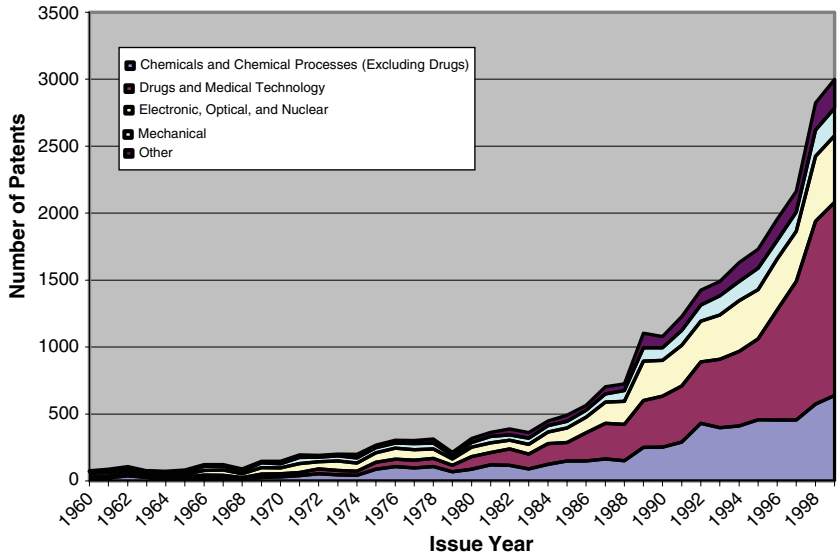

Figure 3. Technology field of carnegie university patents, 1960–1999.

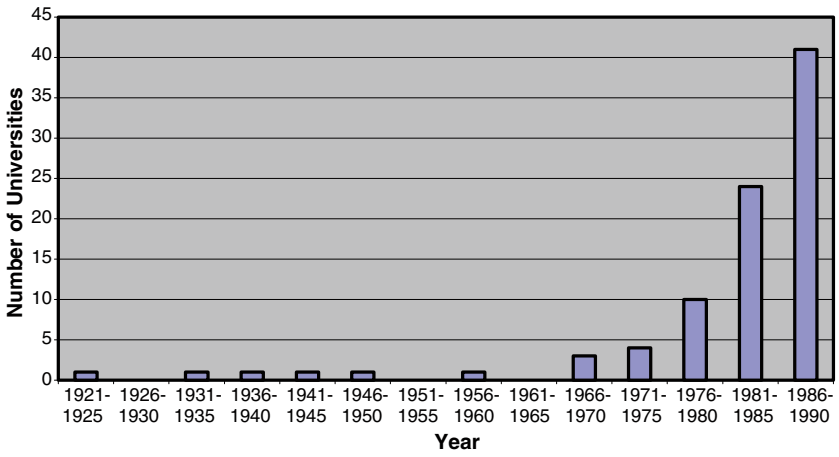

Figure 4. Year of "Entry" into technology transfer activities.

Association of American Universities,[7] the Commissioner of the US Patent and Trademark Office,[8] and the *Technology Review*, edited and published at MIT.[9]

These characterizations of the positive effects of the Bayh-Dole Act cite little evidence in support of their claims beyond simple counts of university patents and licenses. But growth in both of these activities predates Bayh-Dole and is rooted in internationally unique characteristics of the US higher education system. Nor does evidence of increased patenting and licensing by universities by itself indicate that university research discoveries are being transferred to industry more efficiently or commercialized more rapidly, as Colyvas *et al.* (2002) and Mowery *et al.* (2001) point out. Current research thus provides mixed support at best for a central assumption of the Bayh-Dole Act, i.e., the argument that patenting and licensing are necessary for the transfer and commercial development of university inventions.

In addition, of course, these "assessments" of the effects of the Bayh-Dole Act fail to consider potentially negative effects of the Act on US university research or innovation in the broader economy. Some scholars have suggested that the "commercialization motives" created by Bayh-Dole could shift the orientation of university research away from "basic" and towards "applied" research (Henderson *et al.*, 1998), but there is little evidence of substantial shifts since Bayh-Dole in the content of academic research. Since US university patenting and licensing before and after 1980 has been concentrated in a few fields of research, notably biomedical research, a field characterized by blurry lines between "basic" and "applied" research, this finding should not come as a great surprise.

A second potentially negative effect of increased university patenting and licensing is a weakening of academic researchers' commitments to "open science," leading to publication delays, secrecy, and withholding of data and materials (Dasgupta and David, 1994; Liebeskind 2001). There are indications in this research on university patenting and licensing that the "disclosure norms" of academic research in specific fields have been affected by increased faculty patenting, but more research on this issue is needed. Moreover, the Bayh-Dole Act is not solely responsible for any such changes in disclosure norms—increased opportunities for commercial gain from basic research in such fields as academic biotechnology, as well as the overall strengthening of intellectual property rights in the US, are not themselves directly linked to Bayh-Dole. Nonetheless, given the importance assigned by industrial researchers to the "nonpatent/licensing" channels of interaction with universities in most industrial sectors, it is crucially important that these channels not be constricted or impeded by the intensive focus on patenting and licensing in many universities.

Finally, the effects of any increased assertion by institutional and individual inventors of property rights over inputs to scientific research have only begun to receive serious scholarly attention. Patenting and restrictive licensing of inputs into future research (''research tools'') could hinder downstream research and product development (Heller and Eisenberg, 1998; Merges and Nelson, 1994).

Although there is little compelling evidence as yet that the Bayh-Dole Act has had negative consequences for academic research, technology transfer, and industrial innovation in the US, the data available to monitor any such effects are very limited. Moreover, such data are necessarily retrospective, and in their nature are likely to reveal significant changes in the norms and behavior of researchers or universities only after a long lag. Any negative effects of Bayh-Dole accordingly may reveal themselves only well after they first appear.

4. International ''emulation'' of the Bayh-Dole Act

Although the evidence on the effects of the Bayh-Dole Act suggests that its ''catalytic'' effects on university–industry technology transfer are limited, a number of other OECD governments are considering or have adopted policies emulating the Act's provisions.[10] In Denmark, a 1999 law gave public research organizations, including universities, the rights to all inventions funded by the Ministry for Research and Technology. Under Denmark's previous policy (established in 1957), all such rights had reverted to employees (OECD, 2003). The German Ministry for Science and Education in 2002 altered the ''professor's privilege,'' which gave academic researchers primary responsibility for the decision to file for patent protection on inventions and granted them the rights to any resulting patents. The new policy requires that academic inventors inform their employers of potentially patentable inventions two months before papers disclosing such inventions are submitted for publication, and grants universities four months to determine whether they wish to file for patent protection.[11] In France, a 1999 law authorized the creation of technology transfer offices at universities, and in 2001 the Ministry of Research ''recommended'' that universities and public research organizations establish policies to assert their rights to employee inventions (OECD, 2003). The Canadian Prime Minister's ''Expert Panel on the Commercialization of University Research'' recommended in 1999 that universities retain ownership of inventions resulting from publicly funded research, and ''be held accountable for maximizing returns to Canada,'' noting that ''the proposed IP policy framework will inspire a transformational shift in culture within Canadian universities, as happened in the US with the passage of the Bayh-Dole Act in 1980'' (Public Investments in University Research, p. 28).[12]

In varying degrees all of these initiatives cite Bayh-Dole as one justification. Nevertheless, they in fact differ significantly from the Act, which sought to transfer ownership for publicly funded inventions from government agencies to universities and other nonprofits. In contrast to Bayh-Dole, all of the policies described in the previous paragraph, along with similar new policies in other European countries (e.g., Austria, Ireland, and Spain) ''have focused on changing employment laws so that university professors are no longer exempted from legislation that gives employers the IP generated by employees'' (OECD, 2003, p. 11), and seek to transfer ownership from individual inventors to universities.[13] Similarly, the ''Japanese Bayh-Dole Act'' of 1999 shifted ownership from individual inventors to universities (http://www.nsftokyo.org/rm04-05.html). These initiatives thus ignore one of the central justifications for Bayh-Dole, i.e., that government ownership of publicly funded inventions impedes their commercialization.

In addition to changes in intellectual property policy an employment regulations, a number of related initiatives aim to stimulate the organization and activity of technology licensing offices. Thus the Swedish, German, and Japanese governments (among others) have encouraged the formation of external ''technology licensing organizations,'' which may or may not be affiliated with a given university (see Goldfarb and Henrekson, 2003, for a comparison of Bayh-Dole and Swedish initiatives to enhance university–industry technology transfer).

As this discussion suggests, these initiatives to emulate Bayh-Dole differ from one another and from Bayh-Dole itself. The policy proposals and initiatives display the classic signs of international emulation—selective "borrowing" from another nation's policies for implementation in an institutional context that differs significantly from that of the nation being emulated. Nonetheless, these initiatives are based on the belief that university patenting was an essential vehicle for effective transfer of technology from universities to industry and that Bayh-Dole was essential to the growth of university–industry interaction in science-based industries in the US during and after the 1980s. These views appear to be based on a misreading of the limited evidence concerning the effects of Bayh-Dole, however, and on a misunderstanding of the factors that have encouraged the long-standing and relatively close relationship between US universities and industrial innovation. More importantly, like Bayh-Dole itself, these initiatives focus narrowly on the "deliverable" outputs of university research, and ignore the effects of patenting and licensing on the other, more economically important, channels through which universities contribute to innovation and economic growth.

In as much as patenting and licensing are of secondary importance in most fields, emulation of the Bayh-Dole Act is insufficient and perhaps even unnecessary to stimulate higher levels of university–industry interaction and technology transfer. Instead, reforms to enhance inter-institutional competition and autonomy within national university systems, as well as support for the external institutional contributors to new-firm formation and technology commercialization, appear to be more important.

Indeed, emulation of Bayh-Dole actually could be counterproductive in other industrial economies, precisely because of the importance of other channels for technology transfer and exploitation by industry. A narrow-minded focus on licensing as the primary or only channel for technology transfer can have a chilling effect on the operation of other important channels. There are potential risks to the university research enterprise that accompany increased involvement by university administrators and faculty in technology licensing and commercialization, and uncritical emulation of Bayh-Dole in a very different institutional context could intensify these risks.

5. Conclusion

The relationship between US university research and innovation in industry is a long and close one. Both organized industrial research and the US research university first appeared in the late 19th century and have developed a complex interactive relationship. The unusual structure of the US higher education infrastructure, which blended financial autonomy, public funding from state and local sources with federal research support, and substantial scale, provided strong incentives for university faculty and administrators to focus their efforts on research activities with local economic and social benefits. Rather than being exclusively concerned with fundamental scientific principles, much of US university research throughout the late 19th and 20th centuries focused on understanding and solving problems of agriculture, public health, and industry.

US universities have made important contributions to industrial innovation throughout the past century, not least through by combining advanced research and education. The strong links between education and research sustained a close relationship between the evolving scientific research agenda and problems of industry or agriculture, while at the same time providing a powerful and effective channel (in the form of trained students) for the transfer and application of much of this knowledge to industry and other economic sectors. In addition, many university researchers in engineering and medical schools maintained close ties with the users of their research and their graduates in industry, medical practice, and agriculture. The important role of universities in industrial innovation, particularly during the post-1945 period, also relied on institutions external to the university, including venture capitalists, equity-based financing of new firms, and high levels of labor mobility between academia and industry.

Based on these considerations, we believe that much of the growth in licensing and university-based "spinoffs" that has occurred since the passage of the Bayh-Dole Act almost certainly

would have occurred in the absence of this piece of legislation. After all, US universities were active patenters and licensors for decades before 1980, and much of their patenting and licensing activity since 1980 has been highly concentrated in a few fields, at least some of which also have benefited from rapid growth in public research funding and significant advances in basic science.

The Bayh-Dole Act thus appears to have been neither necessary nor sufficient for much of the post-1980 growth in university patenting and licensing in the US. Moreover, given the very different institutional landscape in the national higher education systems of much of Western Europe and Japan, it seems likely that the "emulation" of Bayh-Dole that has been discussed or implemented in many of these economies is far from sufficient to trigger significant growth in academic patenting and licensing or university–industry technology transfer. Indeed, there is some question as to the necessity of a "patent-oriented" policy to encourage stronger research collaboration and technology transfer. And the potential risks associated with such policy changes have received too little attention.

Notes

1. According to Katz and Ordover (1990), at least 14 Congressional bills passed during the 1980s focused on strengthening domestic and international protection for intellectual property rights, and the Court of Appeals for the Federal Circuit created in 1982 has upheld patent rights in roughly 80% of the cases argued before it, a considerable increase from the pre-1982 rate of 30% for the Federal bench.
2. See Hall and Ziedonis (2001) for an analysis of the effects of the CAFC and related policy shifts on patenting in the US semiconductor industry.
3. Data on total academic R&D were obtained from National Science Board (2000), Appendix Table 4-4.
4. As we have pointed out elsewhere (Mowery *et al*., 2001) The Bayh-Dole Act did not dramatically affect the patenting and licensing activities of universities that had long been active in this area, such as Stanford University and the University of California. Indeed, the biomedical patents and licenses that dominated these institutions' licensing revenues during the 1980s and 1990s had begun to grow before the passage of the Bayh-Dole Act. Columbia University, an institution with little experience in patenting and licensing before 1980 (and an institution that prohibited the patenting of inventions by medical faculty until 1975), also had filed for its first "blockbuster" patent before the effective date of the Act. Nevertheless, the Act did increase patenting of faculty inventions at both Stanford and the University of California, although many of these patents covered inventions of marginal industrial value and did not yield significant licensing royalties.
5. "Regulatory reform in the US in the early 1980s, such as the Bayh-Dole Act, have [sic] significantly increased the contribution of scientific institutions to innovation. There is evidence that this is one of the factors contributing to the pick-up of US growth performance …" (OECD, *A New Economy?*, 2000, p. 77).
6. "Possibly the most inspired piece of legislation to be enacted in America over the past half-century was the Bayh-Dole Act of 1980. Together with amendments in 1984 and augmentation in 1986, this unlocked all the inventions and discoveries that had been made in laboratories throughout the US with the help of taxpayers' money. More than anything, this single policy measure helped to reverse America's precipitous slide into industrial irrelevance. Before Bayh-Dole, the fruits of research supported by government agencies had gone strictly to the federal government. Nobody could exploit such research without tedious negotiations with a federal agency concerned. Worse, companies found it nigh impossible to acquire exclusive rights to a government owned patent. And without that, few firms were willing to invest millions more of their own money to turn a basic research idea into a marketable product." (Economist, 12/14/02).
7. "In 1980, the enactment of the Bayh-Dole Act (Public Law 98-620) culminated years of work to develop incentives for laboratory discoveries to make their way to the marketplace promptly, with all the attendant benefits for public welfare and economic growth that result from those innovations. Before Bayh-Dole, the federal government had accumulated 30,000 patents, of which only 5% had been licensed and even fewer had found their way into commercial products. Today under Bayh-Dole more than 200 universities are engaged in technology transfer, adding more than $21 billion each year to the economy."
8. "In the 1970s, the government discovered the inventions that resulted from public funding were not reaching the marketplace because no one would make the additional investment to turn basic research into marketable products. That finding resulted in the Bayh-Dole Act, passed in 1980. It enabled universities, small companies, and nonprofit organizations to commercialize the results of federally funded research. The results of Bayh-Dole have been significant. Before 1981, fewer than 250 patents were issued to universities each year. A decade later universities were averaging approximately 1000 patents a year."
9. "The Bayh-Dole Act turned out to be the Viagra for campus innovation. Universities that would previously have let their intellectual property lie fallow began filing for – and getting patents at unprecedented rates. Coupled with other legal economic and political developments that also spurred patenting and licensing, the results seems nothing less than a major boom to national economic growth."
10. A recent OECD report (2003) argues that these initiatives "echo the landmark Bayh-Dole Act of 1980" (11).
11. The new policy aims to ensure that "more inventions are brought to patent offices before they get published" and "is

supposed to lead to active licensing transfer from university to industry and to more companies being founded on the basis of intellectual property conceived within the university environment'' (Kilger and Bartenbach, 2002).

12. Although no uniform government policy governs the treatment of university inventions in the United Kingdom, ''there is now an increasing trend for Universities to claim ownership'' over academic inventions (Christie *et al*., 2003 p. 71).

13. In contrast to these initiatives, Italy passed legislation in 2001 that shifted ownership from universities to individual researchers. According to Breschi *et al*. (2004), this policy change has ''the declared intention of finally providing the right economic incentives for individual scientists to undertake ''useful'' (that is ''patentable'') research'' (2).

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