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Reconsidering the Bayh-Dole Act and the Current University Invention Ownership Model

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ABSTRACT

The Bayh-Dole Act of 1980 provided U.S. universities with the right to commercialize employees' inventions made while engaged in government-funded research. This paper argues that the current university invention ownership model, in which universities maintain de jure ownership of inventions, is not optimal either in terms of economic efficiency or for advancing the social interest of rapidly commercializing technology and encouraging entrepreneurship. We argue that this model is plagued by ineffective incentives, information asymmetries, and contradictory motivations for the university, the inventors, potential licensees, and university technology licensing offices (TLOs). These structural uncertainties can lead to delays in licensing, misaligned incentives among parties, and obstacles to the flow of scientific information and the materials necessary for scientific progress. The institutional arrangements within which TLOs are embedded have encouraged some of them to become revenue maximizers, rather than facilitators of technology dissemination for the good of the entire society.

We suggest two alternative invention commercialization models as superior alternatives. The first alternative is to vest ownership with the inventor, who could choose the commercialization path for the invention. For this privilege the inventor would provide the university an ownership stake in any returns to the invention. The inventor would be free to contract with the university TLO or any other entity that might assist in commercialization. The second alternative is to make all inventions immediately publicly available through a public domain strategy or, through a requirement that all inventions be licensed non-exclusively. Both alternatives would address the current dysfunctional arrangements in university technology commercialization.

1. Introduction

The belief that the commercialization of federally funded research results was retarded by the federal ownership of the intellectual property rights led Congress to pass the Bayh-Dole Act (BD) in 1980.[1] Based on minimal evidence, it was believed that government-owned patents were insufficiently utilized (Berman, 2008; Eisenberg, 1996). In the name of providing the fruits of university inventions to society in an efficient, effective, and socially optimal manner,[2] Congress designed the BD Act to allow federal contractors including universities to claim title to inventions made as a result of federally funded research. It also standardized the procedures for vesting the control of federally funded research inventions in contractors (Mowery et al., 2004; Slaughter and Rhoades, 2004).[3] The popular press and others have hailed the resulting university ownership model as a boon to society (e.g., The Economist, 2005; OECD, 2003). On the other hand, there have been an increasing number of critiques (Glenna et al., 2007; Nelson, 2004; Washburn, 2005, and, in particular, Litan et al., 2007) and complaints from faculty inventors and potential licensees concerning the current model.

The growing commercial interface between the university and industry has sparked an outpouring of research (for reviews, see Rothaermel et al., 2007; Shane, 2004). Given this interest, critically examining the effects of current implementation of the BD model is important not only for the United States, but also for the rest of the world, as other nations adopt BD-like models in the belief that it is the best way to ensure the commercialization of university inventions (Geuna and Nesta, 2006; Mowery and Sampat, 2005).

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[1] Most elite research universities already had Institutional Patent Agreements with various federal funding agents, though these varied by agency. Eliminating this variation was another important goal of the legislation (Mowery et al., 2004).

[2] We define efficiency, as accomplishing a task in the most rapid, least resource intensive manner possible.

[3] The Federal government retained a royalty-free, non-exclusive license.

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Drawing upon the now substantial body of literature on the operation of university technology licensing offices (TLOs), technology licensing, and university–industry relationships, in general, our orientation depends most directly upon the contributions of three different theoretical research traditions. The first tradition is evolutionary institutional economics pioneered by Sidney Winter and Richard Nelson and includes Wesley Cohen, David Mowery, Nathan Rosenberg, and their students. They examined the historical evolution of the current university ownership model and found that it is having a discernable, though debatable in terms of importance, effect on the scientific enterprise (see Mowery et al., 2004; Cohen et al., 2000). The second tradition that has framed our thinking represents the sociological network analysts roughly grouped around Walter W. Powell. Although less overtly concerned with the institutional and social impacts on the university or efficiency, their detailed research on the network linkages between university and industry and the role and operation of TLOs has led them to hypothesize that there is a hybridization of researchers in these two different institutions (Owen-Smith, 2003; Rhoten and Powell, 2007). The final tradition that informs this paper is the legal tradition examining the current university invention licensing model (Eisenberg, 1996; Lemley, 2007; Rai and Eisenberg, 2003). These theories inform our understanding of the macro-level institutional structures and networks within which the inventor, TLO managers, and the inventors operate.

The paper utilizes stylized models about how inventions are commercialized. We recognize that the current organizational arrangements are evolutionary outcomes influenced by economic, legal and political decisions by a variety of actors, local and remote. A world of complicated intra- and interorganizational networks of actors has evolved to manage the interface between the university and the commercial sector. While accepting these theoretical models for our orientation and acknowledging the importance of historical analysis to understand the reasons for the current conjuncture, we apply some useful insights from agency theory and transaction costs economics to elucidate how the contemporary university invention ownership model yields outcomes that are contrary to the supposed intent of the BD Act. So, while building upon these theories, we use microlevel analysis to show that the current university invention ownership model is plagued by ineffective incentives, information asymmetries, and contradictory goals for inventors, potential licensees, the university, and university TLOs.[4] These structural uncertainties lead to commercialization delays, unnecessary expenses, "gray" markets in inventions, difficult to enforce restrictions on inventors, misaligned incentives among parties, and delays in the flow of scientific information and the materials necessary for scientific progress. This state of affairs exists even though there are simpler and more effective alternatives.

By ceding the commercialization rights for university inventions made in the course of conducting federally funded research to universities, the U.S. Congress made – perhaps not entirely wittingly – a profound technology policy decision and validated a new university invention commercialization model. An understanding of the model and its difficulties is achieved by reviewing the background to the BD Act and the current university ownership model. Since the overarching goal of BD was to facilitate of the use of federally funded inventions, we examine whether TLO behavior comports with the claim of facilitating technology transfer. This is followed by an analysis of the TLO-inventor relationship describing the contradictory goals, information asymmetries, and perverse incentives resulting from the university ownership model. Although possibly justified at the time, we show through an analysis of the structural position, property rights, and actor incentives that the current BD-based university invention ownership model results in suboptimal outcomes.[5]

The BD model is not the only one for organizing technology diffusion and commercialization. Robert Litan et al. (2007), among a number of recommendations, suggested the first model we discuss, which vests invention ownership in the inventor.[6] This idea was not new. In an interview Norman Latker, one of the key advocates within the National Institutes of Health for change in the disposition of inventions made using Federal research funds, told Elizabeth Popp Berman (2009) that "assigning the invention to the inventor would have been his first choice." This path was not taken. The second model we discuss aims to improve the diffusion of university inventions by weakening the property rights in the inventions. The first variant of this model would place all university inventions in the public domain as part of the intellectual commons (Dasgupta and David, 1994; Rhoten and Powell, 2007).[7] The second variant proposed by Richard Nelson (2004) would limit universities to offering non-exclusive licenses for inventions. After critiquing the current university ownership model, each of these alternatives is examined; though we concentrate on the inventor ownership model because it has been less discussed in the scholarly literature.

2. Background

The congressional motivation in passing BD emanated from the debatable proposition that patents resulting from federally funded research were unexploited due to insecurity regarding their ownership (Berman, 2008; Eisenberg, 1996; Mowery et al., 2004). There was also a belief that the university could be the source of innovations that would reinforce U.S. economic preeminence (Berman, 2008; Brooks, 1993; Stevens, 2004). The public policy objective was to incent the transfer of the benefits of federally funded research to society. In many cases, universities, as a condition of employment, had already claimed employees' inventions. With the rights to inventions made with federal funding came an affirmative obligation to market them actively (Eisenberg, 1996; Mowery et al., 2004; Sampat, 2006). The implicit conceptual model held that universities would be sufficiently self-interested to respond to the offer of invention ownership and market the inventions to industry (Rafferty, 2008).

As with much legislation, BD was the result of lobbying efforts by interested parties—in this case, corporations and university licensing officials hoping to monetize these inventions (Eisenberg, 1996: 1726; Sandelin, 2007; Washburn, 2005). For the universities, the desire to appropriate the fruits of their employees' federally funded research was undoubtedly fueled by the emergence of the biotechnology industry, whose promise of riches to invention owners culminated with the spectacular initial public stock offerings of Genentech in 1980 and of Cetus in 1981 (Kenney, 1986).[8] For university administrators these riches seemed attainable since patents in pharmaceuticals are more easily defended than in other fields,

[4] We do not use the term "technology transfer office," because the goal and charge of nearly all of these offices is invention licensing. For a comprehensive review of the literature on TLOs, see Phan and Siegel (2006). For an excellent review of the literature on university-based entrepreneurship, see Rothaermel et al. (2007).

[5] For an overview of intellectual property rights and university TLOs, see Thursby and Thursby (2007).

[6] On inventor ownership, also see Greenbaum and Scott (2008).

[7] Rai (2005) has proposed strengthened and more aggressively enforced Federal march-in rights to ensure the inventions are practiced. In theory this should work, however in practice both federal government bureaucrats and TLOs would find this an onerous and difficult thing to do.

[8] The 1981 Cetus IPO was the largest ever to that date raising $108 million.

and therefore particularly well suited to monetization by research-only organizations such as universities.[9]

At the time BD was passed, far fewer university researchers, particularly in biology, had an interest in commercializing inventions. This disinterest changed in the 1980s as biology, the largest recipient of federal funding, underwent a technical and commercial revolution making research results more commercializable and, in certain cases, quite lucrative (for an extended treatment of this period, see Kenney, 1986; also Jong, 2006; Colyvas, 2007). In engineering and chemistry there was a long history of commercialization of university inventions, although largely through individual faculty efforts and the Research Corporation (for more see, Mowery et al., 2004 Chapters Two and Three). In many respects BD was a formalization of an extant movement (Berman, 2008), but it served to alert faculty and administrators still operating under the previous more Mertonian social ethos that conditions were changing. Furthermore, it confirmed that it was socially desirable for university researchers to patent inventions. With visions of a new income source, universities that did not have a TLO soon established one.

3. Is a TLO necessary for technology transfer?

Universities have a long history of generating inventions with commercial value, which are used by industry (e.g., Geiger, 2004; Mowery and Sampat, 2001; Rosenberg and Nelson, 1994). And yet, it has only been since the 1970s that TLOs dedicated to commercializing inventions have become commonplace at research universities (Mowery et al., 2004).

One unique feature of universities is that their variety of inventions is far greater than those of any private sector firm. The fact that the importance of patents differs by industry (Levin et al., 1987), as suggested by the patent literature, demonstrates how university TLOs need different procedures, methods, and goals for differing industries (for software, see Williams and Barnett, 2009 and Rai et al., in press). For example, in electronics, software, and engineering, patents are most often used defensively to ward off infringement cases from other firms, though this may be changing (for semiconductors, see Hall and Ziedonis, 2001; Ziedonis, 2003; for nanotechnology, see Lemley, 2005). The significance of university patents in software and electronics in terms of facilitating technology transfer is dubious (Jaffe and Lerner, 2004), as shown by Stanford University's frequent use of non-exclusive licenses (Ku, 2002). If one considers university-affiliated information technology (IT) startups during the last three decades, some did not have university licenses, including Sun Microsystems (Stanford), Yahoo! (Stanford), and Netscape (University of Illinois)[10] while more recent ones, such as Akamai (MIT), Google (Stanford), Lycos (CMU), and Cisco (Stanford)[11] did procure licenses. What is not clear is that TLO involvement was necessary for adoption. If TLOs may not have been vital in assisting the transfer and commercialization process in the IT and engineering fields, then it is possible that TLOs and patents are more valuable in fields such as the biological sciences—an observation that academic research supports (Cohen and Walsh, 2002; Coriat et al., 2003; Lim, 2004; Merges and Nelson, 1990).

Critical case studies provide insight into the significance of TLOs for technology transfer. The most studied and one of the most lucrative university-owned patents ever issued, the Cohen-Boyer (C-B) patent, serves well in parsing the centrality of the TLO in technology diffusion. The C-B patents consisted of a process patent and three quite general composition of matter patents issued during the 1980s on a pioneering and fundamental technique for the creation of genetically engineered microorganisms (Hughes, 2001; Kenney, 1986: 258; Powell et al., 2007).[12] Over its 17-year life, C-B produced in excess of $255 million in revenues for Stanford University and the University of California. The vast majority of these were royalties from human therapeutics developed using the engineering technique.

There have been misunderstandings regarding the role of the C-B patent. For example, Maryann Feldman et al. (2007) concluded that "had it not been for Stanford's enlightened licensing practices, the C-B technology might have been placed in the public domain where the technology could have remained undeveloped or in the laboratories of large established pharmaceutical companies."[13] The fact that C-B was non-exclusively licensed calls this conclusion into question. Niels Riemers, the founder and first director of the Stanford Technology Licensing Office, who was responsible for the patent filing, is quoted as saying that it was already in use at the time of its filing (Reimers as quoted in Sampat, 2006). Within months after being revealed at a 1973 Gordon Conference, university laboratories around the world began using the C-B process. The communities of practice within which scientists are embedded ensure that any powerful new tool diffuses almost immediately.[14] Even if C-B had never been patented, the fact is that in the late 1970s, a swarm of other newly established firms were already practicing the C-B technique. It was being adopted regardless of whether it had been patented or not. Since it was licensed non-exclusively the license operated as a tax (for C-B specifically, see Rai and Eisenberg, 2003: 300; for a general statement, see Mazzoleni, 2006). Reimers understood these marketplace realities and therefore wisely set a low license fee and royalty payments.

A similarly important invention, developed contemporaneously, provides an alternative perspective. In 1975, while working at Cambridge University, Georges Köhler and César Milstein described in a short letter to *Nature* the invention of what came to be known as monoclonal antibodies (MABs), which rapidly became a widely practiced and powerful general-purpose enabling technology.[15] The inventors were aware of its value and explicitly stated in their *Nature* letter that "such cultures could be valuable for medical and industrial use" (quoted in Cambrosio and Keating, 1995: 8). Had the invention been patented, it would have been a basic patent (Oliver and Liebeskind, 2003). In this case, the inventors placed their invention into the public domain.

Following the reasoning of Feldman et al. (2007), one might expect that MABs would languish unused. Yet in 1978, exactly three years after the short letter in *Nature*, the first MABs-based firm, Hybritech, was established in San Diego.[16] Other MAB firms were

[9] Donald Kennedy (1981), then president of Stanford University captured this when he observed that, "these firms are being capitalized so that much of the incremental value is being realized before a product is on the market or before it is even very sure that there will be one."

[10] Netscape rewrote the original browser code, but called their browser, Mosaic. The University of Illinois sued what was then Mosaic Communications. A settlement was reached in which the University of Illinois received approximately $3 million and Mosaic Communications changed its name to Netscape.

[11] In the case of Cisco, Stanford threatened to sue because it used some proprietary software developed at Stanford. Ultimately, a settlement was reached in which Stanford received $19,300 in licensing fees, $150,000 in royalties, and product discounts. Stanford was also offered equity in Cisco, but that was refused due to university policy.

[12] According to Reimers and others, Hughes (2001), which is based on interviews with nearly all of the key actors, is the definitive history of the C-B patent.

[13] Of course, once the Cohen-Boyer technology was published, it could no longer have been patented by anyone except the inventors, so it is not possible that a large pharmaceutical firm could have patented the technique.

[14] For discussion of communities of practice, see Lave and Wenger (1991).

[15] On general purpose technologies, see Bresnahan and Trajtenberg (1996).

[16] According to Garnsey (undated), Hybritech was established in 1978 by Ivor Royston, a UCSD professor; Brook Byers, a venture capitalist; and Howard Birndorf, a researcher in Royston's lab. Royston had been a visiting researcher at Cesar

also established and large pharmaceutical firms integrated MAB technology into their tool kit. This diffusion suggests, at least in regard to general-purpose technologies such as C-B or MABs, that there is little reason to believe that such inventions will remain unused due to a lack of proprietary protection, or even that their diffusion would be retarded. Both C-B and MABs contributed to an efflorescence of entrepreneurship, but patenting had no impact on their adoption. Of course, when these techniques are used to create a pharmaceutical or MAB assay, a patent can provide protection for commercialization.

The previous examples originate from the inception of the biotechnology industry. The invention of human stem cell lines is a contemporary example. A number of human stem cell lines were developed at the University of Wisconsin, Madison (UWM), and the patent rights were assigned to the Wisconsin Alumni Research Foundation (WARF), a private entity (Jain and George, 2007).[17] Aware that stem cells might have commercial possibilities, WARF designed a licensing agreement to be applied to every user, even university researchers. The licensing agreement stipulated that WARF could "reach" through and demand royalties for any invention using their stem cell lines. UWM, through its agent WARF, has a long history extending back to the 1930s of aggressively dunning potential licensees, whether firms or other research institutions (Sampat and Nelson, 2002; Rai and Eisenberg, 2003). To illustrate, WARF demanded royalties from any related invention by the non-profit California Institute for Regenerative Medicine, which was established by California voters to accelerate stem cell-related research. Under public opinion pressure and NIH threats to use its march-in rights retained under BD (Eisenberg and Rai, 2004), WARF withdrew its demand that the California Institute pay royalties (WARF, 2007). This incident demonstrates that, in this case, income-not technology diffusion-was the overriding goal. WARF, a model for many other TLOs, has the operational attributes of a profit-making entity.

Such concerns are echoed in an increasing number of university patents on biological materials, many of which are the result of taxpayer-funded research (Mowery and Ziedonis, 2007; Walsh et al., 2007). For example, Walsh et al. (2007: 1193) found that "even for transfers from one academic institution to another, where NIH guidelines [that suggest that reach-through rights and royalties not be used] are likely to apply, 29 percent of [material transfer agreements] included a reach-through right and 12 percent included a request for a royalty." These findings suggest that at least some TLOs, in their search for more licensing revenues, are treating the research enterprise itself as an opportunity to generate revenues. The next section builds upon these findings to suggest that the current ownership-based TLO model is a troubled organizational solution for maximizing the social benefits of university-generated inventions.

4. The inventor-TLO relationship

The basic relationship in the university ownership model consists of a researcher disclosing an invention to the TLO. In this transaction there are two actors: the inventor and the university TLO. If the invention is licensed, there is a third actor—the licensee. One added complication is that the inventor may become the licensee. The following sections examine the role of the TLO and the inventor, but not explicitly the licensee. This examination elucidates the contradictions and dilemmas inherent in the university invention ownership model.

4.1. The TLO

Even the largest TLOs are small parts of a major research university; many of which have research budgets exceeding $500 million. TLOs have different organizational locations within the university, but most often they are situated under the administrator responsible for research. Over the last two decades, TLOs have grown in number, size, and cost. In 2006, approximately 20 percent of the TLOs had more than fifteen professionals (AUTM, 2006). In such large TLOs, direct and indirect expenditures are likely to be approximately $2 million.[18] The financial returns from TLOs vary significantly, but the most successful have gross returns of between $20 million and $60 million, while most have returns under $5 million. There are outliers such as NYU, which received $197 million in 2006, and Columbia University, which did not report its income to AUTM (AUTM, 2006).

While meant to be used for further research, TLO income is attractive to administrators because the funds are, in fact, largely unencumbered, thereby providing wide discretion on how they are spent. Often the support monies for TLO personnel can originate from public funds, either federal or state. This asymmetry offers a powerful incentive—restricted funds can be spent to operate the TLO, while earnings are far less restricted. The strength of this incentive is difficult to measure, but it may be considerable as more flexible funds are invariably in short supply.

The academic writings on TLOs have often been theoretically confused, and any analysis of the TLO's role must first clarify these confusions. For example, some scholars model the TLO in a principal-agent framework (e.g., on principal-agent, see Jensen and Meckling, 1976). Markman et al. (2004) consider the TLO as the inventor's agent, an excellent idea, but in the current situation, an impossible formulation because the inventor has no contractual authority over the TLO. A somewhat different formulation by Jensen and Thursby (2001) models the TLO as an agent of both the inventor and the university. Though not precisely correct, the relationship does indicate the contradictory situation that the TLO faces because it is an agent of the university, although for success it depends upon the inventor's knowledge and cooperation. Oddly, the researchers are also university agents. But in this particular relationship, the TLO has only a tenuous and highly mediated control of the inventor, particularly if the inventor is a tenured professor. For these reasons, characterizing the inventor-TLO relationship as one in which the TLO is an agent of the inventor is fallacious.

A more realistic formulation of the TLO-inventor relationship is vital. Consider the impossible world of zero transaction costs in which there is perfect information for all parties regarding the value of an invention, no time constraints, infinite bargaining time on the part of the inventor and in the marketplace, costless transactions between the university, inventor and the licensing firm, or just between the university and inventor/entrepreneur in the case of a startup. In such a case one would have a socially optimal outcome. Perfect information allows all parties to see the same future benefit from an invention, and bargaining among the parties results in a costless sharing of this benefit, regardless of invention ownership. In such a world the assignment of property rights would only

Milstein's Cambridge lab. After establishing the firm, Byers flew to England to negotiate with the Medical Research Council to license the technology only to discover that it was in the public domain. An outcome that has to this day affected British university technology policy—the proverbial tale of the fish that escaped (for discussion, please see Tansey and Catterall eds. 1997).

[17] It is a common misconception that at the University of Wisconsin inventions belong to the inventor. This is true in cases where the funding for the inventions is not sponsored. If the sponsor is the Federal government all the inventions are the property of the University, which assigns them to WARF.

[18] This is an estimate based on the assumption that professionals would cost approximately $150,000 each if all benefits and overhead costs were included. If the TLO is filing large numbers of patents or litigation, then costs rapidly spiral.

affect the distribution of wealth among the parties, not the allocation of resources (Coase, 1960). But, as Coase (1988: 174–179) made clear, this assumption of zero transaction costs operates only as a device to illustrate the essential aspect of transaction costs in the real world.

A basic rule for economic efficiency is that entitlements should be assigned to the party most likely to make optimal market judgments. Calabresi and Melamed (1972) analyzed entitlement protection through property and liability rules in a world characterized by transaction costs and imperfect information. They concluded that property rights should be assigned so that the resulting market allocation comes closest to the optimum given the particular set of transaction costs that parties face. These insights can be applied to intellectual property rights in university inventions. That is, a parallel can be drawn between the concept of least cost avoider in the case of externalities, and the least cost (or most effective) innovator in the case of technology transfer.

University commercialization of inventions can occur either through licensing to a third-party firm or to the inventor's startup. Building upon Jensen and Thursby (2001), Robert Lowe (2006) develops a base model in which the university inventor owns the invention, and then introduces the current university ownership model in which the university TLO is an intermediary as required by BD. The two cases allow a comparison of the welfare and economic efficiency differences between these two property right assignments. In Lowe's model, the inventor has the option of forming a startup instead of licensing the invention.

When the university TLO is introduced, as the intermediary between the inventor and the potential licensees, the outcomes change. The TLO must expend resources to market and manage the invention, and in return negotiate a license contract with an outside firm. Or in the case of the inventor founding a startup, it would negotiate a contract with the inventor. When the inventor forms a startup, the inventor pays an initial fixed fee to the university for use of the invention and royalties—which are contingent upon successful commercialization (of course, the university could also demand equity). This produces two differences from the base case in which the inventor owns the invention. First, if the royalties are based on revenues, the profit and output of the firm is reduced, resulting in a Pareto inferior outcome. Second, because of the reduced output and license costs, the inventor is worse off and the university is better off.

One justification for university ownership is that it administers and manages the intellectual property for the university inventor, i.e., it performs a service. This justification, though, most reasonably applies to those cases in which the invention is licensed. If the inventor is intent upon establishing a firm, there is no economic reason for university TLO involvement. In cases in which the university negotiates with an outside firm, it might be argued that the TLO has an advantage in terms of institutional power and licensing experience. In such a case, the TLO can improve upon the base case contract if it can find licensees that the inventor could not find or secure higher licensing fees. This improvement can be Pareto superior in that both the inventor and the university are made better off by the TLO's knowledge of the market. If the TLO does not have superior knowledge, then the university simply taxes the invention, presumably resulting in less effort by the inventor, a Pareto inferior outcome.

An affirmative case for university ownership has been advanced by Thomas Hellman (2007). His model assumes that the TLO, acting on behalf of the university owning the patent, has knowledge superior to that of the inventor on how the invention may be used and by which firms. The general result is that the inventor is better off by delegating the search for licensees to the TLO—a situation that is optimal. There is, of course, a problem in this formulation because the inventor is not delegating, and the TLO already has ownership. If the TLO is not more effective in search than the inventor, then it is preferable that the inventor has the rights (Hellman, 2007: 28).

Does the TLO, as Hellman (2007) argues, have search capabilities superior to the inventor? This scenario is questionable as the inventor is steeped in the literature of the invention, knows current research competitors whether they are working in public or private sector institutions, and has ideas about the invention and its possible applications. Thursby and Thursby (2004) confirm this in their observation of "the extreme importance of personal contacts between the firm's R&D staff and university personnel."[19] Not only are the inventors likely to have the best knowledge of which firms might be interested in an invention, but they also play a vital role "in the transfer of technology after an invention is made."

Market knowledge is often treated as costless, but as Cohen and Levinthal (1990) and many others have shown, valuing and using knowledge depends upon the development of costly absorptive capacity. In a business setting, this capacity is usually not general but rather sector specific. Universities have a more difficult situation as the knowledge generated by their researchers is dispersed across a variety of fields.

When we allow into the model the reality that transaction are costly, property right assignment matters and errors can have efficiency effects as well as distributional effects. The most effective exploiter of an invention could be either the inventor or the TLO, depending upon the experience and capabilities of both with respect to the particular invention. Unfortunately, because perfect information does not exist in reality, these cannot be known a priori. If transaction costs and time loss between the inventor and TLO are low, then a mistake in property right assignment will be corrected with the party placing the highest value on the invention bargaining for that right. But if transaction costs and/or time loss are important, then an incorrect assignment can result in economic loss.[20]

Frequently, there is an asymmetry in transaction costs between the university inventor and the TLO. Suppose a TLO represents the most effective vehicle for exploitation, but the ownership resides with the inventor. How will these parties react? Both will likely realize that the TLO is the most effective manager of the invention, and the inventor will either sell the rights to the invention to the TLO or contract the TLO services. In this case, the gains from such transactions exceed their costs, and the economically efficient result of TLO management is achieved as it becomes either the owner or the inventor's agent.

Now suppose that the inventor would be most effective in commercializing the innovation, but the entitlement has been granted to the TLO. There are likely to be costs to the inventor in securing the rights to the invention. Alternatively, the TLO could contract for the services of the inventor to commercialize the invention. Presumably, this occurs in the current model by the inventor being motivated through receiving a share of the invention's revenues. This complicated set of conditions would be avoided by consistently awarding the rights to the inventor who would then decide on the commercialization route.

The TLO as an organizational form has contradictions and hard-to-fulfill mandates. Regardless of whether they are well-managed, TLOs occupy a conflicted position in any technology commercialization process. Based upon observational research, Owen-Smith and Powell (2001) found that their well-managed TLO at an entrepreneurial private university operated smoothly with considerable success. The other TLO at a large public university experienced significant operational difficulties. Simply put, a badly

[19] Also, see Agrawal (2006).

[20] Time loss may not be a problem at all TLOs. Katharine Ku (2008) states that the Stanford TLO aims to provide the inventor with an answer in less than one month.

managed TLO can impede technology transfer. To illustrate, in their research at elite universities with presumably well-managed TLOs Colyvas et al. (2002) found a case in which the TLO's desire to protect the university interest in an invention complicated the transfer process. In our discussions with campus inventors, we have heard many cases, anecdotes, and rumors about other cases in which the need of the TLO to protect its proprietary position complicated or retarded commercialization.

As a bureaucratic entity, the TLO may also be the victim of university politics as decisions to patent may not be made purely on merit. To illustrate, if an invention is not patented and marketed, inventors may threaten to leave, taking their laboratory and grants with them. Resignation by professors with large federal grants results in the loss of significant overhead income.[21] In an effort to retain faculty members who attract large grants, the TLO's superiors may demand favorable but inefficient decisions.

Recent modeling exercises in industrial organization economics, using a large number of simplifying assumptions, have argued that TLOs provide important benefits to inventors and potential licensees. For example, Heidrun C. Hoppe and Emre Ozdenoren (2005) developed an economic model arguing that the TLO offers advantages to the inventor because the TLO can pool inventions from several laboratories thereby providing better service. This variant on the economies of scope argument is problematic if the technologies arise from a wide variety of communities of practice. The difficulty when this model is applied to the real world is that the TLO owns the inventions regardless of its ability and even desire to provide service. Conversely, if the TLO is competent and can use its economies of scope, then in an inventor–ownership model, the inventors would recognize and value this advantage and voluntarily contract with TLOs.[22] Given that inventors are embedded in networks of other inventors, reputation effects would result in the selection of the most effective TLOs and demise of the ineffective ones (Brown and Duguid, 2001; Bercovitz and Feldman, 2008; Powell et al., 1996).

In another modeling exercise, Ines Macho-Stadler et al. (2007: 483) demonstrate that a TLO could develop a positive reputation among invention buyers through vetting and "shelving" lower-quality disclosures, thereby raising potential buyer's belief regarding the expected quality and presumable price. They hypothesize that this model would result in selling fewer but more valuable inventions. In this case, they assume that the TLO is more capable of judging an invention's value than the potential licensee or the inventor—a dubious assumption. Since the TLO, not being omniscient, would concentrate its efforts on only those inventions it considered most valuable, it could easily overlook potentially valuable inventions. In any case, all TLOs have an incentive to develop good reputations. Invention quality is not the only issue affecting potential licensees. These theoretical findings shed no light on whether the inventor or the university should retain ownership rights. Presumably, inventor ownership would improve TLO operation by replacing default institutional ownership with event-specific decision making.

TLOs and their personnel are, for good reason, often measured in terms of revenue. For these TLOs, the emphasis naturally shifts to extraction of the greatest amount of income. Because nearly every university is based on annual budgets, the dominant strategy would be to favor up-front payments from deep-pocketed large firms and to pursue aggressively only those inventions that the technology licensing officers believed had the greatest potential pay-off (Lemley, 2007).[23] Concentrating on only inventions with clear pay-offs could inadvertently limit university research spin-offs. In a study of the commercialization of university-derived inventions in electron microscopy by small startup firms, Cyrus Mody (2006: 80) concluded that "policy-makers cannot predict which [research] communities will generate profits, and will hinder all if they try to encourage only profitable ones at the expense of the rest."

Other perverse incentives exist. Larger, more successful TLOs can have a longer term perspective and in order to maximize return may use patent troll-like strategies such as pursuing "submarine" patents (see, for example, Rai et al., in press).[24] An excellent example is Columbia University's secret efforts to extend the Axel transformation patents by asking for Patent Office continuations. They succeeded in getting the contested patent issued two years after the first group expired (Harvard Journal of Law and Technology, 2004; Colaianni and Cook-Deegan, 2009).[25] This strategy suggests that the primary goal of Columbia's TLO is not to transfer technology but to maximize revenue. Such extraordinary efforts to extend the patents are entirely logical when one considers that Columbia faced losing annual revenues exceeding $50 million. With such revenues, the original goals of the university such as contributing to knowledge transfer and social welfare are at risk of becoming by-products.

In cases in which the inventor wants to form a firm to exploit the invention, there is a high probability that the inventor's interests will diverge from the interests of the revenue-maximizing TLO and will converge with that of a prospective licensee, the professor's firm. In fact, Markman et al. (2005) found that the most "attractive" combinations of technology stage and licensing strategy for new venture creation, i.e., early stage technology, combined with licensing for equity, were the least likely to be favored by the university. This was because many university TLOs are risk-averse bureaucracies focused on short-term revenue maximization. Oddly enough, knowing this, there have recently been recommendations that TLO managers be provided with incentive pay (Link et al., 2007), which can only lead to increased short-termism with high up-front licensing fees that discourage entrepreneurship and encourage greater aggressiveness on the part of the TLO personnel in encouraging/demanding disclosure.[26]

Because the function of a TLO in many cases is not to "transfer" technologies, but to monetize inventions, it usually negotiates

[21] The total overhead earned by a research university is significant. For the sake of argument, if one assumes that 80 percent of Ohio State University's research budget for 2006 of $652,329,000 is billed at an overhead rate of 50 percent, then the total annual overhead income is in excess of $172 million. Even at universities with large TLO income, such as Stanford, which earns approximately $50 million per year, such overhead is important. In 2006 Stanford would have received by the same calculation $179 million in overhead.

[22] Interestingly enough, this particular stream of theorizing has a historical precedent in the United States. During the 19th Century technology/patent brokers emerged to assist inventors in monetizing their inventions (Lamoreaux and Sokoloff, 2001).

[23] Predicting in advance the pay-off from a new invention is difficult. For example, Katharine Ku (2008) has stated that they "did not know Google would be successful at its inception or that the technology was particularly revolutionary."

[24] A "submarine" patent is an informal term for a patent first published and granted long after the original application was filed. In such cases one set of individuals may invest significant sums in developing a body of knowledge without being aware that there exists a firm that already has a patent on this knowledge. These patents violate one of the fundamental goals of the patent system, which is to make the knowledge public so that others can be aware of it. When the submarine patent finally emerges, other users may have made significant investments that are now hostage to the patent owner.

[25] The virulence of this drive for more income was on display when Columbia University lobbied a U.S. senator to add an amendment to a completely unrelated bill in an effort to extend the Axel patents (Harvard Journal of Law and Technology, 2004: 596).

[26] This aggressiveness mitigates a TLO's willingness to release any inventions pro publico bono. A salient example has been a reticence on the part of a number of universities to provide favorable licensing terms to poorer nations. For discussion, see Butler (2007) and Nelsen (2003).

a sale of rights to a commercial entity. The commercial entity, because it operates in specific business areas, almost invariably has a better understanding of the value of the invention than does the TLO. In addition, the commercial entity has the possibility of approaching the professor directly for a consulting relationship to organize a "gray" technology transfer (Link et al., 2007). For this reason, the licensing party almost always has superior information and alternatives.

The most common response of any party in a situation in which other parties to the negotiation have superior information, and possibly alternative channels for commercialization, is to hesitate until more information is available. If the TLO is risk-averse, then the instinct to hesitate will be even more compelling. Since the TLO has ownership, procrastination incurs no direct cost, though there may be enormous (but never known) opportunity costs. Should the TLO act hastily, the outcome is likely to be suboptimal for the university and the inventor. This disadvantage is further complicated in cases in which the inventors believe themselves to have superior information; in such cases, they may lose faith in the TLO and refuse further cooperation.

As a TLO operates, it acquires a reputation, which affects future relationships (Owen-Smith and Powell, 2001; Macho-Stadler et al., 2007).[27] A positive reputation for managerial excellence encourages trust on the part of both the inventor and the licensees. When unaddressed difficulties are experienced by either the inventors or the licensees, a negative reputation for the TLO can ensue, decreasing trust.

A negative experience suffered by the inventor or entrepreneur can be costly. The licensing experience of Marc Andreessen, one of the original developers of the Mosaic browser while he was a student at the University of Illinois, illustrates the pitfalls. When Andreessen joined James Clark to form Netscape in 1994, they attempted to negotiate a license with the University of Illinois but found the process so frustrating that they ultimately rewrote the browser code entirely. By 1999, the University of Illinois had successfully collected a total of $7 million from the Mosaic copyrights, but the ill feelings of the Netscape founders almost certainly cost the university a far greater amount in lost donations (Kesan and Shah, 2004: ff454; Reid, 1997: 37). Conversely, James Clark – a Stanford University professor until he left in 1982 to form Silicon Graphics to exploit the fruits of his university research – explicitly mentioned his positive experience as motivating his decision to donate $150 million to Stanford (Capart and Sandelin, 2004). Frustrating entrepreneurs through difficult financial and contractual demands is likely to be so costly in terms of future donations that it far outweighs the gains from licensing. As with any organizational unit, TLOs are boundedly rational. They may pursue their office's interest to the detriment of the university's overall interests.

If the TLO is badly managed, or so small that it lacks sufficient personnel qualified in the specific technology underlying the disclosure, the result can be the frustration of technology transfer and the cumulative development of a negative reputation. Some TLOs have reputations for being difficult or incompetent, and are thus either shunned or approached by potential licensees adversarially (Greenbaum and Scott, 2008; Owen-Smith and Powell, 2001; Silverman, 2007). TLOs may develop adversarial relationships with the faculty discouraging further disclosures, contribution to patent maintenance and extension, and participation in the transfer process. A reputation for adversarialism encourages the inventor(s) to circumvent university regulation by transferring inventions to off-campus entities outside the official disclosure system.

To sum up, the TLO is the centralized intermediary for technology licensing and, by virtue of the fact that it owns all inventions, has complete responsibility for commercialization. This is despite the fact that the inventor is often the best informed actor regarding the science of the invention and, often its possible applications and potentially interested licensees. This does not, however, by any means imply that TLOs have no role. Indeed, well-run TLOs are in a position to attract inventors on the basis of the services they offer.

4.2. The inventor

Many researchers choose a university career because of its relatively unstructured, unsupervised, and collegial environment. Implicit in the models many economists and policy-makers have of the technology transfer process is the assumption that university inventors are employees in the same way as corporate researchers are employees. Yet, the labor market within which a university inventor, particularly a professor, is embedded differs from that of a corporate researcher. To illustrate, it is nearly impossible to terminate the employment of tenured faculty. Further, faculty members engage in unique specializations in which the substantive content may not be understood even by their first-line "supervisor," the department chairperson, who is a colleague. To evaluate the performance of faculty members, administrators rely upon departmental colleagues and the external invisible college of peers to pass upon research quality, funding requests, and personnel decisions.

A faculty member's work process is largely immune to direct control and supervision by the administration. Research support is predominantly extramural, for specified projects, and subject to little control or strategic direction by university administrators. Many valuable faculty outputs, such as textbooks, belong to the faculty and not to the university. In contrast, the source of the corporate researchers' funds is, as a rule, internal; managers have direct control over the funds and employment can be terminated at will. To model professors with the same constraints, motivations, and structural position as employees of a for-profit firm or, for that matter, a civil service bureaucracy, is flawed. University inventors have significant independence, and they are subject to little effective oversight—a recipe for complicated relationships and a lack of corporate-style accountability.

Though university researchers are required to disclose and assign their inventions to the university, it is not easy to monitor or enforce this requirement (Siegel et al., 2003; Markman et al., 2008). The literature suggests that the best way to encourage disclosure on the part of university employees is to increase their share of the invention's income. Lower royalty rates encourage firm formation (Di Gregorio and Shane, 2003), implying that researchers are sensitive to the opportunity costs of forming their own startup. This incentive assumes that university inventors are necessarily motivated to receive the highest royalty possible.[28] In cases in which the inventor has a significant financial stake in the firm licensing the technology, royalties diminish the firm's profit, thereby creating contradictory motives for the owner-inventor.

When an inventor discloses to a TLO, tensions may arise if the inventor believes, rightly or wrongly, that the TLO is mismanaging the process or generating insufficient income. Should inventors believe that the TLO is investing insufficient resources in their invention or that the TLO is incompetent, compliance with the university's rules can decrease and relationships can become

[27] For an exhaustive discussion of the economics of reputation, see Cabral (2005).

[28] The share of inventor's royalties differs by university. For example, the University of California Website states that an inventor receives 35 percent of the net income after the direct costs of administering an invention are subtracted from the gross income.

antagonistic. In the case of prior disclosures, the inventor has little recourse. However, for later inventions, alternatives to disclosure exist. In contrast to a firm in which there presumably is much greater monitoring of researchers, the university is congenitally unable to supervise strictly without violating its core values.

Many professors have established firms or developed intimate relationships (very often including tangible economic incentives) with firms undertaking research in fields closely allied with their university research. This creates the conditions for the emergence of a "gray market" for inventions (Markman et al., 2006; Mody, 2006: 79). This gray market is difficult to measure but is likely substantial. From a sample of National Institutes of Health, National Cancer Institute grantees, David Audretsch et al. (2006) found that over 20 percent of the professors had established firms in their field of expertise without university licenses. In a study using patents, Markman et al. (2008: 33) found that over 42 percent of the professors who did patent, for one or more of their inventions they had bypassed the university TLO. Paralleling Rappert et al.'s (1999) findings, Markman et al. (2008) found that professors not disclosing patentable inventions were more likely to establish a firm. From a large population of university faculty patents, Thursby et al. (2009) find that 26 percent of all faculty patents were assigned directly to firms, however they note that these patents were less basic than those assigned to universities. From this they conclude that some of the firm-assigned faculty patents may be the fruits of consulting work and thus not all are necessarily part of the gray market.

An inventor has many options for circumventing the university TLO. For example, it is possible to establish a firm prior to generating a patentable invention and then transfer the "discovery" of a valuable result to the firm. This shift is often not difficult because the tacit knowledge can be transferred through a graduate or post-doctoral student joining the firm. To realize the transfer process the university researcher can then accept equity and serve on the scientific advisory board. In computer science and other engineering disciplines, transferring inventions is often easy, as the location of the inventive activity is fungible, and there is less written evidence such as laboratory notebooks to establish the genesis of invention. For the TLO to investigate university faculty members is often difficult and divisive—although universities do investigate faculty and staff for a variety of reasons. Worse, if violations were found, then potentially embarrassing disciplinary action may have to be taken. Motivated inventors have ample opportunity and means for circumventing the TLO.

A variant on the gray market strategy is to publish the invention, vitiating the possibility of a patent. Given that the inventor has superior knowledge, it may be possible to found a firm to exploit the now "open source" invention. This strategy is likely to be simplest in engineering and computer science, but can be feasible in biomedical and scientific instruments (Mody, 2006). One drawback is that raising venture capital to appropriate the open source knowledge may be more difficult.

Alternatively, inventors can disclose the invention, and then provide no further cooperation with the TLO. In such cases the TLO has little leverage. Non-cooperation ensures that licensing will be difficult, and it could compel the TLO to provide a low-cost license to the inventor. For the inventor, the costs of non-cooperation are minimal.

From an economic perspective, the inventor's position is curious. Inventors are legally obligated to disclose their inventions. And yet, enforcement is difficult. Link et al. (2007) recognized this and concluded that "it also seems prudent for universities that place a high priority on formal technology transfer to place a higher value on patenting, licensing, and start-up formation in promotion and tenure decisions" (Link et al., 2007). To suit the needs of the current TLO model, these authors are suggesting a transformation of the university incentive structure. Research, teaching, and contributions to the general societal knowledge pool would vie with patent generation and firm formation as university goals. They would raise an appendage of the university and a minor funding source to a central goal of the university, without any evidence that such a change in policy would create either socially desirable effects or generate greater economic activity.

5. Alternative models

Given the contradictions, misaligned incentives, and inefficiencies inherent in the extant patent ownership model, we propose that two other models be considered. The first model is based on the premise that inventor ownership will result in greater and faster technology commercialization. What the model cannot answer is the normative argument of whether the university should be rewarded for being the institution within which the invention was gestated. We suggest that ownership be vested in the inventor, precisely the individual who best understands the invention, its potential, and is most likely to have ideas for potential customers.

The second model is based on weaker ownership rights and has two variants (Eisenberg, 1996; Nelson, 2004; Rhoten and Powell, 2007). In the first variant, all university inventions would be placed in the public domain and available to all users. In the public domain model the university administration would no longer be involved in licensing. The university would return to its role as a platform for research and instruction. A less drastic variant is mandatory non-exclusive licensing. In the non-exclusive licensing model, inventor disclosure and university ownership continues unchanged requiring only that licenses are non-exclusive.[29] In the non-exclusive variant university ownership is not questioned.

5.1. *Inventor ownership*

The inventor ownership model decentralizes the invention dissemination decision to those closest to the knowledge creation process and to the one most likely to have the best information. This model already exists as a default practiced in cases in which universities decline to exploit the invention and the inventor petitions the federal sponsor for the rights (Chew, 1992).[30] If inventors owned the rights, then they could choose to use the university TLO or any other organization to commercialize the technology, commercialize the technology themselves, or place the invention in the public domain. In an inventor-ownership model, they would be the principals, and they could secure an agent.

There are benefits beyond efficiency. In fields such as computer science software inventors often wish to place their programs into the public domain, but many TLOs demand that these programs be protected and licensed. In the inventor ownership model, the inventor would make the decision unfettered by institutional constraints. An inventor ownership model would relieve researchers of the affirmative obligation to assist in the patenting of inventions made in their laboratory, and to assist the university in prosecuting patents. Inventions could be dedicated to the public without

[29] Reviewers have pointed out that in this variant, the choice of exclusive licenses is precluded and this might stymie commercialization of certain inventions such as those requiring years of expensive pharmaceutical testing. One possibility is to add an exception stating that exclusivity could be granted for inventions requiring significant follow-on investment. We are agnostic about such an exception because it could lead to litigation or system "manipulation with guile." All social rules and arrangements have cases in which they are inefficient compared to others. Ultimately, the question is which one operates most simply, transparently, effectively, and efficiently over an entire class of cases. The greater the complications, the greater the possibility for gaming. Case study research could provide us with greater insight into the various trade-offs.

[30] It is possible for the inventor to petition the funding agency for the rights to an invention, but this is time-consuming and costly.

violating employment contracts. This is important because often, a public domain arrangement would best serve the public good by rapidly diffusing the technology.

Beyond the efficiencies, the institution of an inventor-owned patent model would remove the temptation to judge faculty members based on the financial return they can provide the university. Transferring the property rights to the inventor raises normative questions regarding the propriety of allowing individuals to capture the entire benefit from inventions developed with public monies in the social space of the university commons. This could be addressed through employment contracts providing that the university receive a tithe from its inventors of, for illustration purposes, five percent of the equity or licensing proceeds of any invention university researchers make in their fields of expertise. The tithe should be sufficiently small so as not to discourage inventor commercialization. This pre-arrangement would shrink the burgeoning gray market vexing the current model. Addressing normative issues is not precluded in an inventor ownership model.

Inventor ownership is not a panacea, but it would not worsen existing problems. In cases in which an invention has multiple inventors, regardless of the ownership model, priority and ownership must be determined. One argument for TLO ownership is that, if there are multiple inventions with multiple and differing authors, the TLO as the owner can aggregate these inventions. This becomes more difficult in the inventor ownership scenario, as there is no central "sovereign." Whether a TLO can do this aggregation more effectively than the parties or, if necessary, the civil courts, is not clear. If the TLO decides unfavorably to certain claimants, the decision is likely to be challenged in the courts. If inventors are at separate institutions, the ownership determination process will be more complicated since not only the inventors, but also their respective TLOs, are involved. Given the greater number of parties with interests involved, arriving at a settlement is likely to be more difficult.

The university administration's role in an inventor ownership model would change in that it would not be responsible for technology licensing. It would return to its earlier and more important charge—ensuring that faculty members discharge their institutional duties. Inventor ownership might result in the exploitation of students, but there is no evident reason that this exploitation would be more prevalent than it is today—and the administration would not have the appearance of conflicts of interest. If such problems were a concern, then faculty members could be required to report efforts to exploit university-related (or even all) inventions they were commercializing. This would create greater transparency. Inventor ownership should not generate serious new problems, while alleviating some of the current difficulties and inefficiencies.

Another valid concern regarding the inventor ownership model is whether it would be more likely to stifle the flow of information and materials. There is no definitive answer to this concern, but our suspicion is that faculty inventors may be more sensitive to pressure from their peers than TLOs may be. Nonetheless, if university researchers have their own firm staffed with professional managers, their willingness to provide information and materials is likely to be reduced—but this would also be true if the professor has a firm licensing university technology. No model can eliminate all of the tensions that, almost by definition, exist when an invention is transferred from the non-profit world of the university to the for-profit world of business.

The inventor ownership model would remove research commercialization from the control and mission of the university administration and would decentralize it to the inventors. We have shown the efficiency reasons for such a model and have argued that in terms of the speed and effectiveness of technology transfer the investor ownership model would result in superior outcomes. In terms of information and material flow and good governance within the university, there is little reason for inventor ownership to be socially inferior.

Inventor ownership need not lead to the demise of the university TLOs. Technology transfer and commercialization requires competence and skills across a wide range of activities, including technology assessment, patent search, marketing, patent law, and intellectual property issues. This competence must be combined with an appreciation of the specific science and industry associated with each particular invention, and then brought to bear in the process of negotiation with one or more firms, possibly including the inventor's start-up firm. In fact, TLOs might benefit as they would be relieved of the pressure to manage inventions that have little prospect of success, but for which they have a responsibility. Their location on campus would be a strong advantage. Many faculty inventors not wishing to expend time and effort on commercializing their inventions, but also hoping that the invention would be successfully commercialized, are likely to voluntarily turn to their local TLO. This prospect is not fanciful. In 1969 when Niels Reimers established the Stanford TLO, he was faced with having to convince inventors of the utility of the TLO.[31] These starting conditions may explain why the Stanford TLO retains a strong "service" orientation (Ku, 2008; Owen-Smith, 2005). Altering ownership rights would force TLOs to operate as service organizations and to shift the relationship from one structured to serve the TLO to one structured to serve the inventor-owner.

In most university settings the TLO will be in the best position to provide these services, and this fact will be appreciated by most university inventors. It is in those cases where there is a significant difference of opinion between the TLO and the inventor regarding the process of commercialization, or where the TLO is not capable of providing these services, that difficulties occur. In discussing alternatives to the current Bayh-Dole regime, a system where the inventor holds the IP would resolve most of these difficulties.

Consider the situation from a quasi-game theoretic perspective. Suppose in one case that an inventor mistakenly believes that their invention is of commercial value, or that the TLO is pursuing the wrong path to commercialization. If the inventor, as the owner of the IP, acts on these mistaken beliefs, this will become apparent over time. The cost of an approach that allows inventors to make mistakes is that some inventions will fail to be commercialized in a timely fashion. The benefit would be that the TLO would be vindicated, which would be observed by the university community. Over time the value of the TLO would be accurately determined. By decentralizing the decision making to each inventor, errors in judgment are decentralized. Suppose that the TLO is dysfunctional. If the TLO controls all of the innovations, it is possible for it to affect every invention disclosed at the university, and for the inventor there is no easy recourse. Unlike the first case where decentralized decision making allows for multiple paths to commercialization, the current Bath-Dole system prohibits such experiments in alternative paths if the TLO believes they are not in its interest. Note also, that by allowing inventors to follow their own path to commercialization, many of the most unpleasant disagreements between university inventors and TLOs could be avoided.

In most instances both the inventor and the TLO will appreciate each other's competence in different aspects of the commercialization process. The inventor is the most informed actor on the science and often on the applications of the invention, while the TLO will have the greatest experience in negotiating a license to commercialize the invention. In those cases where these beliefs are jointly held by the TLO and the inventor, the same basic path

[31] See Nelson (2005) concerning Reimers first successful patent and licensing of software for musical synthesizers.

to commercialization will be followed whether the inventor or the TLO holds the IP to the invention. In those cases, though, where there is significant disagreement as to the best means to commercialize the invention, it is better that the IP is held by the inventor. In the next subsection, we briefly explore cases in which the inventor ownership model has existed.

5.1.1. Experiences with the inventor ownership model

Because the inventor ownership model currently does not exist in the United States, there are no direct domestic comparisons.[32] Two universities, Stanford and Wisconsin, had policies in the past that allowed campus inventors to appropriate inventions that were made with "gift" accounts or foundation grants and thus not restricted by the funding agent. Even more pertinent, the University of Cambridge is a useful comparison because up until a new mandatory university ownership scheme was implemented beginning in 2001, researchers owned their inventions. Though not discussed here, the University of Waterloo has the strongest policy of inventor ownership in Canada, and is widely recognized as having the greatest number and most valuable spin-offs of any Canadian university (Bramwell and Wolfe, 2008).[33] The final comparative case is Europe, which has a variety of different models and where technology transfer, until recently, almost entirely occurred outside official university channels.

Stanford has a long history of entrepreneurial technology transfer (Lowen, 1997). In an archival study of the evolution of the Stanford Office of Technology Licensing procedures, Jeanette Colyvas (2007: 468) shows in the biomedical field that initially there were four quite different models for organizing the relationship between university laboratories and firms. Eventually, these models merged into a single institutionalized model that combined elements of the early models.[34] She concludes that "money and entrepreneurship were outcomes rather than an input" (Colyvas, 2007: 474). In the biomedical field, "the subsequent outpouring of royalties, many years after the original research (and early debates about how to organize the intersection of commerce and academe), caused the remaking of existing arrangements, resulting in the recasting of technology transfer practices."[35] For Stanford, as Colyvas and Powell (2007) show, commercialization activity in biology grew most rapidly in the 1990s.[36] Our conclusion is that Stanford University faculty, students, and staff would have commercialized their inventions or, as in the case of BD, their inventions would have been used regardless of the presence of a TLO, though we are also certain that the Stanford TLO helped many inventors.

While the Stanford TLO was less central in commercializing the digital technologies, in the 1980s the most visible technology transfers occurred in this field. For example, in 1982 Sun Microsystems (Sun was an acronym for Stanford University Network), a firm commercializing networked workstations, resulted from an entrepreneurial collaboration between three Stanford graduate students and a UC Berkeley graduate student. In 1984 Cisco Systems was formed by two Stanford staff members who built routers to link the then separate Stanford local area networks. Similarly, in 1982, Silicon Graphics commercialized a software program, the Geometry Engine, that Professor James Clark and graduate students had developed at Stanford. Though in each of these cases the Stanford TLO was involved, its actions were not critical to commercial success. At Stanford there is evidence for successful technology commercialization without the TLO. There is little evidence that technology transfer increased since the 1994 decision to require that all inventions developed at Stanford be disclosed to the TLO. Fortunately, there is little evidence that technology transfer has been frustrated by the Stanford TLO, which has a reputation for being service-oriented (Colyvas, 2007).

The University of Wisconsin, Madison, shares some similarities with Stanford, as university faculty to this day own any inventions that are not encumbered by sponsor restrictions. Of course, because of the BD Act, all federally funded inventions must be disclosed to the university, which assigns them to WARF (Whitehorse, 2009). In contrast to Stanford, there is no evidence of large and significant spin-offs exploiting unlicensed UWM technology. The technology licensing model at UWM was established in 1925 through the voluntary decision by a faculty inventor to set up an off-campus entity, WARF, to administer what became a lucrative patent for using ultraviolet irradiation to increase the Vitamin D content in food. Later, WARF received and administered the rights to the blood thinner dicoumarin in 1947 and the rodenticide Warfarin in 1948. These inventions were licensed to large firms and almost certainly would have been commercialized either with or without patents.

UWM has had large numbers of spin-offs during the last four decades and WARF has successfully licensed many technologies to them. In a study we undertook to identify all direct UWM spin-offs, as defined by at least one founder directly affiliated with UWM before formation of the new firm, we found that UWM had from 1957 to 2006 spun off 112 firms.[37] Unfortunately, we have no way of identifying the licensing status of these firms. The preponderance of these spin-offs came after 1980, and spin-off formation accelerated in the 1990s, which roughly parallels the findings of Colyvas concerning Stanford-licensed biomedical spin-offs. A number of UWM's most important licensing successes came prior to BD and were voluntary assignations.

Since rules concerning ownership of patents arising from federally funded research are applied uniformly across the country, it is not possible to contemporaneously compare different inventor ownership models in the United States. It is noteworthy, though, that Stanford was the source of many valuable university startups after BD, yet before the university's 1994 policy mandating disclosure of all inventions to the TLO.

Until recent policy changes, the purest case of a global-class research university practicing inventor ownership is the University of Cambridge. Though there are no international comparisons, it is also quite possible that it has been the most fertile university in terms of technology-based entrepreneurship outside the United States (Garnsey and Heffernan, 2005; Druilhe and Garnsey, 2004; Myint et al., 2005; Segal Quince Wicksteed Ltd., 1985).[38] With reference to inventor ownership, Elizabeth Garnsey and Paul Heffernan (2005: 1129) describe the situation at Cambridge:

Central administration was minimal until after 2000 and did not have the means or inclination to manage technology.. .. From 1986, British universities had rights to intellectual property in work funded by the Research Councils. The University of Cambridge was

[32] The Research Corporation and WARF come directly from the inventor ownership model, created by faculty inventors who were concerned about the negative effects of direct university ownership (Mowery et al., 2004).

[33] The University of Waterloo spin-off that has been the greatest success is Research in Motion, which was founded by two graduate students.

[34] The first important income-generating patent for the Stanford TLO was filed in 1970 for frequency modulation in electronic music instruments (Nelson, 2005).

[35] In terms of entrepreneurship, the blockbuster 1980 Genentech initial public stock offering demonstrated the potential value of research results in the new genetic engineering technologies (Kenney, 1986).

[36] Despite the critical importance of Stanford's TLO as a model, the most important early Bay Area biotechnology firms were spin-offs of the University of California, San Francisco (Jong, 2006: 252).

[37] This data is available from the authors.

[38] There is no existing database to compare entrepreneurship across universities. A possible contender to this is China where the Chinese Academy of Sciences and elite universities have been the source of large numbers of spin-off businesses, both in technology and other fields (Chen and Kenney, 2007; Lu, 2000).

unusual in vesting this entitlement to inventors on its staff. In laissez-faire mode, no active support for technology transfer was provided in the early period. In 2001, this policy was changed, as the University of Cambridge conformed to new UK government rules implementing a BD-like university ownership model.

There is no complete count of the number of Cambridge spin-offs, but there is evidence that the number has been large. For example, Celine Druilhe and Elizabeth Garnsey (2004), using a rigorous methodology of counting only direct founder spin-offs, found 109 direct university spinouts. From 1970 to 2004, the Department of Engineering spun off 34 firms. Acorn Computer, which spun out of the University Computer Laboratory in 1979, gave rise to 32 second-generation firms (Garnsey and Heffernan, 2005). These past successes created an environment conducive to further entrepreneurship.

In 2001, a BD-like model was implemented at Cambridge whereby the University took ownership of all faculty inventions. The driving force for the change from inventor ownership was national government pressure and subsidies to create university TLOs. There was an uncritical acceptance that BD-mandated university ownership was responsible for the successful commercialization of university research (Breznitz, 2008)—a classic case of organizational mimesis described by DiMaggio and Powell (1983). While it is too early to be certain of the ultimate effect of this transition, in a study of biotechnology spinouts, Shiri Breznitz (2008) found that from 2001 – the new model was implemented through 2004 – the number of biotechnology spin-offs decreased, even while the UK and global population of biotechnology firms increased. Her results indicate that implementing BD might be retarding technology diffusion, at least in terms of researcher entrepreneurship, the mechanism that made Cambridge the most successful entrepreneurial region in Europe. The Cambridge case provides a clear-cut before-and-after case study—and, though further study is needed, thus far the evidence suggests that a BD model did not increase either technology transfer or entrepreneurship.

Until recently, in Japan and many European nations, inventor ownership has been the norm and universities did not have TLOs. In addition, these nations had little visible university-derived entrepreneurship. National and regional governments, often at the urging of academics from the United States, came to believe that the lack of commercialization through startups was explained by the absence of a BD mechanism. Ignored was the fact that, in most cases, there was minimal technology-based entrepreneurship in the society as a whole. For this reason – and when compared to U.S. universities such as Stanford and MIT – it appeared as though there was a dearth of technology transfer.[39]

The conclusion that there was little or no technology transfer prior to BD or BD-like policies was always dubious. For example, Kenney and Florida (1994) showed that technology transfer by Japanese public university professors was to existing businesses and came through "under-the-table" consulting, as all compensated professorial consulting at national universities was forbidden at the time. In addition, there was an established system of dispatching corporate researchers to work in university laboratories where they learned the technologies. It is difficult to judge how effective the system was, but there was indeed technology transfer. Rene Carraz (2008) studied patenting practices at Tohoku University, one of the elite research universities in Japan, before and after Japan implemented a BD-like law. Only two years after the implementation of this law, professorial patenting with firms fell by more than 50 percent, while direct university patenting increased dramatically, even as total university-based patenting was essentially unchanged. This finding suggests that inserting a TLO intermediary into the technology transfer process changed the ownership of patents, but did not change the quantity. In this case, if the goal of BD was commercialization, then inserting a TLO intermediary was at best a wash, and could be subtracting value by adding an unnecessary intermediary.[40]

The Continental European case is complicated because each nation has its own policies and practices. In a recent article, Geuna and Nesta (2006) summarize the available evidence finding that in the case of Europe "the rapid rise of academic patenting in the closing quarter of the 20th century was driven more by the growing technological opportunities in the bio-medical sciences (and maybe also in ICT) and the feasibility of pursuing those opportunities in university laboratories, than by policy changes affecting the universities' rights to own patents arising from publicly funded research." Most patents were not owned by the university. For example, Crespi et al. (2007) in a study of 9000 European Patent Office inventors found that 82 percent of the patents by university personnel were not university-owned. Similar results are available for other Continental European nations (Azagra Caro and Llerena, 2003; Balconi et al., 2004; Meyer, 2003; Saragossi and van Pottelsberghe de la Potterie, 2003). Finn Valentin and Jensen (2007) found that after Denmark passed BD-like legislation academic patents owned by industry decreased. They did not observe this in Sweden, which did not change its inventor ownership system. These studies demonstrate that inventor ownership systems can have significant transfer without official university involvement. This transfer occurs even in nations without the entrepreneurial support networks existing in the most successful U.S. regions.[41]

The evidence from Stanford and UWM provides anecdotal support to our argument for a new ownership regime. Stanford had some important spin-offs that did not use the TLO. At UWM, as at Stanford, there undoubtedly would have been many spin-offs regardless of the ownership model. The University of Cambridge is the clearest case in showing that an inventor ownership model can be successful in transferring technology and encouraging entrepreneurship. The European and Japanese experiences with inventor ownership demonstrate that TLOs are not necessary for technology transfer. Unfortunately, there are few published studies regarding the changes in technology transfer given the ownership model changes occurring as European nations adopt BD-like policies. Technology transfer does occur in environments without university ownership, and the University of Cambridge shows that this transfer can be substantial.

5.2. *Weaker ownership rights models*[42]

A requirement that all inventions generated through federal support be placed in the public domain or, in a less radical variant, only licensed on a non-exclusive basis has been suggested (Eisenberg, 1996; Nelson, 2004). Since non-exclusive licensing is a "tax," and shifts the invention rents from one actor to another, this variant would "socialize" a part of the value of the inventions (Rhoten and Powell, 2007). For basic process innovations, even in biology, an "open" strategy is as effective as, or even more effective than, either exclusive or non-exclusive licensing in encouraging technological transfer and progress. In many engineering-based

[39] Unfortunately, when explaining the lack of startups in their nation or locality, few foreign BD advocates objectively assess the overall research quality of their universities, which, with few exceptions and by most objective measures, were far inferior to the U.S. leaders. This is significant because research on technology transfer and entrepreneurship shows that elite research universities are dramatically more successful than others.

[40] We thank an anonymous reviewer pointing out this formulation.

[41] On entrepreneurial support networks, see Kenney and Patton (2005).

[42] For an extended discussion of this, see Rhoten and Powell (2007).

Table 1
Schematic comparison of university invention ownership regimes.

	Bayh-Dole (current model)	Inventor ownership model	Weaker ownership rights model	
			Non-exclusive license variant	Public domain variant
Locus of decision making	TLO (centralized)	Inventor (decentralized)	See Bayh-Dole column	Community
Technology diffusion	TLO has total control. Performance determined by TLO's knowledge, capability, and institutional issues	Inventor chooses channels based on their knowledge and capability. Can contract for assistance.	Operates as tax on users. If sufficiently low may have no impact.	Freely available but no direct incentive based on ownership
Income	TLO responsible, captures income, and shares with various stakeholders. Income can be great, in certain cases, but usually small.	Inventor captures all (though possible to provide university with automatic share)	Can be great with fundamental process innovations, but could diminish for products benefiting from exclusivity.	Not applicable
TLO and endowment	Indeterminate	Using TLO voluntary. Gifts from grateful inventors?		
Well managed TLO	Gifts from grateful inventors		See Bayh-Dole column	Not applicable
Poorly managed TLO	No gifts		See Bayh-Dole column	Not applicable
Local economic development	Licensing bias toward to large firms that are often not local	Indeterminate, if inventor commercializes likely to be local	Only local advantage is proximity to inventor, but large external firms have access	Only local advantage is proximity to inventor, but large external firms have access
Inventor conflicts of interest	TLO has responsibility, university admin financially interested party	University admin not financially interested party	See Bayh-Dole column	Not applicable
Location of problems	If in TLO can affect all inventions (centralized). May also have inventor-level problems (decentralized)	Only inventor-level problems so decentralized	See Bayh-Dole column	Only inventor-level problems so decentralized and related to inventor commercializing against university policy
Adversarial TLO-inventor relations	Good TLOs minimized, Bad TLOs many	Fewer as the relationship is now voluntary	See Bayh-Dole column	Not applicable
Adversarial licensee-TLO relations	Good TLOs minimized, Bad TLOs licensees may refuse to participate	Indeterminate but relations are decentralized	See Bayh-Dole column	Not applicable

Source: Author's compilation.

technologies, patents are not normally considered to be of great significance except to ensure cross licensing (Cohen et al., 2000; Mansfield, 1986). The greatest concern in a non-patenting model would be for proprietary pharmaceutical compounds that might not be developed due to a lack of exclusive patent protection (Levin et al., 1987; Mansfield et al., 1981).[43] There have been successful commercializations of compounds without exclusivity. For example, there were no patents on the anti-cancer drug Taxol, and yet it was successfully commercialized (U.S. General Accounting Office, 2003; Goodman and Walsh, 2001).[44] The case of penicillin – which was not itself patented (although methods of producing it were) – suggests that the Taxol case might not be as exceptional as many believe (Kingston, 1994; Neushul, 1993).

Without patent rights, it is possible that small biotechnology firms might not be able to compete with the large established pharmaceutical firms that have many complementary assets, thereby limiting entrepreneurial startups based upon university biological science.[45] Possibly, a small firm could be established to commercialize non-patented university findings, and, as it operates, to create commercially valuable proprietary knowledge. Alternatively, once the knowledge is in the commons, entrepreneurs may capitalize on the knowledge and form yet other firms. Such dynamics operate in open source software where low costs have allowed entrepreneurs to use the software to create new firms. Whether the IT model would work equally well in pharmaceuticals is uncertain.

For the university, placing inventions in the public domain would ameliorate current concerns about commercialization's influence upon its mission and faculty. In many cases, it would lower the cost and reduce the uncertainty of using new university-developed technologies, thereby accelerating their adoption. Through a radical response to the difficulties of the current model, the public domain model provides an alternative reference point for considering other ownership models. Placing university inventions in the public domain might lead to better solutions compared with using the "perfect world" assumptions underlying most economic models.

6. Conclusion

Organizational arrangements are outcomes of social and political choices, but most arrangements develop an aura of normalness that discourages critical evaluation. Today, the university ownership model is framed as the "natural method" for organizing the interface between university inventions, inventors, and the economic realm. Despite a veritable outpouring of academic research on technology transfer from the university, it is remarkable that the fundamental theoretical and conceptual issues regarding the role and operation of TLOs in technology transfer have until recently

[43] The number of truly exclusive patents licensed by universities is quite small, and as expected are for therapeutic molecules (Pressman et al., 2006).
[44] Florida State University received over $200 million in licensing revenues for patents it had on a technique for synthesizing Taxol.
[45] On complementary assets, see Teece (1986). In the case of pharmaceutical and biotechnology firms, see Rothaermel (2001).

been dealt with only in passing (for exceptions, see Litan et al., 2007; Mowery et al., 2004; Powell et al., 2007). It is so natural that, with few exceptions, academic research on university spin-offs uses data provided by TLOs, which almost always omits firms formed outside the TLO process.

No social arrangement works perfectly in each individual case. Moreover, it is easiest to see the flaws in models that are currently in operation, rather than in proposed solutions, which is why we call for further theorizing and research into how the inventor ownership and public domain models might operate. In Table 1, we schematically compare and contrast each model discussed in the paper on eight separate dimensions: locus of decision making, technology diffusion, beneficiary of direct income stream, impact on potential gifts to university, local economic development, conflicts of interest, adversarial relations between the TLO and inventors, and adversarial relations between the TLO and licensees. It demonstrates that the non-exclusive licensing model is the closest to the current model, while the public domain model is, in many ways, the simplest as it removes all intellectual property protection from university research, but also removes any direct incentive for commercialization. Inventor ownership is a decentralized technology transfer model that offers a plethora of pathways to societal use; many of which are quite standard, but also the possibility of developing unique solutions to particular problems.

The university ownership TLO model is built upon a linear, over-the-transom model of innovation in which the inventor invents, the TLO licenses, and the licensee commercializes. The literature demonstrates that this conceptualization is incorrect as interaction between the inventor and licensee is often critical, and the TLO's role is too often reduced to extracting rents. The TLO adds value when it is a broker connecting the two parties—a case in which university ownership is unnecessary. Intensive qualitative studies, such as Mody's (2006), of university invention-based firms have shown that new firms often have their roots outside the university's institutional arrangements for transfer. The TLO model currently practiced at nearly every U.S. university is unnecessary for entrepreneurship (see Colyvas et al., 2002; Owen-Smith, 2005).

For many important university inventions, patents and TLOs are unnecessary for their diffusion and adoption. We provided anecdotal evidence that, in certain cases, the university ownership model may retard technology diffusion. This impediment arises because in too many cases in the university ownership model, the TLO, which owns the invention, is the least knowledgeable actor in a licensing relationship. This informationally disadvantaged position can foster ineffective decision-making, unreasonable demands, and/or procrastination. The reaction by inventors will be grudging cooperation or efforts to use the gray market—an illegitimate strategy that is easily actualized.

Today, the more experienced and well-managed TLOs are usually the ones with the greatest revenue streams, and therefore are able to sustain a longer, less narrowly focused perspective and, in some cases, a commitment to serving the inventor. The current organizational location and operational imperatives of the typical TLO trap it between its so-called goal of assisting technology transfer, and the primary metric upon which it is measured, revenue-generation. Some larger TLOs, such as WARF and Columbia, have become so focused on revenue that it is possible to argue that TLO income has become of greater importance to the university than disseminating knowledge and operating in the interest of society. There are many other TLOs that are staffed by less skilled and less experienced personnel who by virtue of their structural location are risk-averse and bureaucratic. Also, competent TLO managers may report to superiors that are uninterested, incompetent, or even hostile, thereby impeding their operation. In the university ownership model, inventors are at the mercy of their university's TLO regardless of its competence.

Our two alternative models differ from the current one in dealing with the diffusion of university inventions. Each alternative is the result of a different vision of the social good, economic efficiency, the nature of technology diffusion, and the public purpose. In the first model, the invention remains the property of the inventor or inventors to commercialize or dispose of through any solution including placing it in the public domain. This model places the inventor, someone very knowledgeable about the invention, in the position of deciding the proper approach to technology diffusion. If there is a normative argument for rewarding the university or the Federal government (which in the current model is not compensated directly), as we suggested they could be compensated with a small non-dilutable, silent partner stake in all ventures that professors may undertake in their fields of expertise. The university's role would be to ensure that the commercialization process was honest and transparent. To improve the process further, it might be advisable to appoint a University Commercialization Ombudsman, who would be a faculty member with a record of proven success in commercialization. The Ombudsman would not represent the university, but rather would assist and advise the inventor on creating the firm within the university rules and norms. Such a solution need not lead to the abandonment of the university TLO, as it could offer its services to the inventor for a fee. The university TLO would be placed on a self-supporting basis. Well-managed, service-oriented TLOs would certainly survive and thrive.

Inventor ownership is not a panacea, but we have made a case that it would be superior to the current model. Though unproven scientifically, TLO personnel often suggest that university researchers are, in general, not good entrepreneurs. Though likely true, in many cases, this assumes that university personnel are incapable of learning from their own experience or those of others and seeking assistance. Even supposing researcher incompetence, one advantage is that the incompetence would be decentralized, rather than centralized in an office where it affects all inventors. There will be difficulties in creating a set of norms and common sense rules for ensuring that conflicts of interest and commitment are mitigated. We believe that the advantages will outweigh the difficulties.

The public domain and non-exclusive license variants are also attractive. They escape the problem of inventor ownership by stipulating that university inventions would not be owned at all or would be licensed to all users. For most inventions, such arrangements would be effective and efficient. It is possible that many inventions may leave the university through the gray market, but outflow is already an issue. In this case, the administrative issues regarding commercialization are eliminated. The most often mentioned difficulty with either of these variants is that the exclusive ownership rents derived from patents would no longer exist leading to the question of whether the invention would be commercialized. The illustrations of the unpatented taxol and penicillin showed that commercialization could occur as alternative business models were created.

As Etzkowitz (2002), Rothaermel et al. (2007), and Shane (2004) have shown, university–industry relationships and academic entrepreneurship is a burgeoning field of research, though there has been less research on alternative models for organizing the commercialization of university inventions. There are a sufficient number of foreign universities operating using the inventor ownership model that comparisons can be made. Also, in terms of the history of how the BD model developed, more can be done to build upon the path-breaking research by scholars such as Berman (2008), Eisenberg (1996), Mowery et al. (2004), and Rai and Eisenberg (2003). Finally, we would suggest that Federal funding agencies conduct deliberate experiments by funding a relatively large number of projects that directly stipulate that all inventions are owned by the inventor. After an appropriate interval, the results could be compared and contrasted with the current model.

This article examined the foundations of the university ownership model and built the case that the model itself is fundamentally flawed. We proposed two different models for handling university inventions. Our critique is not alone in cautioning other nations about uncritically adopting of BD model (see, for example, So et al., 2008). It is unfortunate that some policy-makers now subscribe to a belief that passing new regulations mimicking U.S. university patent ownership models will deliver entrepreneurship and new "Silicon Valleys," even to the point that the most successful university technology-based entrepreneurial region in the world outside the United States – Cambridge, England – abandons its successful model. The tenacity of the beliefs in the efficacy of BD are epitomized in an OECD (2003) paper finding that "one of the most urgent tasks is still to raise awareness of and support for university patenting and related activities." Since the last word on this topic has not been written, this paper is an invitation to a debate about how to ensure the greatest social good is derived from university knowledge and inventions.

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