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Universities and Fundamental Research: Reflections on the Growth of University-Industry Partnership

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Universities and Fundamental Research:
Reflections on the Growth of University-Industry Partnerships[‡]

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Abstract

The recent rise in university-industry partnerships has stimulated an important public policy debate regarding how these relationships affect fundamental research. In this paper, we examine the antecedents and consequences of policies to promote university-industry alliances. Although the preliminary evidence appears to suggest that these partnerships have not had a deleterious effect on the quantity and quality of basic research, some legitimate concerns have been raised about these activities that require additional analysis. We conclude that additional research is needed to provide a more accurate assessment of the optimal level of commercialisation.

Keywords: University-Industry Partnerships, Basic Research, Research Joint Ventures (RJVs), Technology Transfer Offices (TTOs), National Co-operative Research Act (NCRA), Bayh-Dole Act.

JEL Class: L31, O31, O32, O33, O34, O38

I. INTRODUCTION

An important trend in several nations has been a substantial increase in university-industry partnerships. In the U.S., such growth can be attributed to several key changes in technology policy that were implemented in the 1980s, with broad bipartisan support. These initiatives include the explicit relaxation of antitrust laws to promote co-operative research, the expansion of public funding to support technology partnerships, and the adoption of various initiatives to promote more rapid diffusion of technologies from universities to firms. Such alliances have become a prominent feature of the "new" knowledge-based economy, which places a stronger emphasis on intellectual property and knowledge capital, as opposed to physical capital and other conventional inputs.

The purpose of this paper is to examine the antecedents and consequences of policies to promote university-industry partnerships. In doing so, we identify the innovation market failures which these policies are designed to address. We also discuss the benefits and drawbacks of increasing the commercialisation of university research.

The remainder of this paper is organised as follows. Section II presents an historical overview of policies to facilitate university-industry partnerships. The following section identifies the innovation market failures that these policies are addressing. Section IV assesses the relative strengths and weaknesses of university-industry alliances. In conducting this analysis, we focus on the critical question of how universities should determine the optimal level of

commercialisation. We conclude with an examination of some concerns regarding university management of intellectual property and offer some suggestions for additional research.

II. ANTECEDENTS OF POLICIES TO FACILITATE UNIVERSITY-INDUSTRY PARTNERSHIPS

In the late 1970's and early 1980's, there was a pervasive slowdown in productivity growth and a concomitant decline in the competitiveness of firms in high-technology industries. An alleged culprit of this downturn in economic performance was a decline in the rate of technological innovation. Concerns regarding these deleterious trends were particularly strong in the United Sates and induced a major re-examination of the goals and tactics of various aspects of U.S. technology policy.

One dimension of innovative activity that was believed to be in dire need of reform was university-industry technology transfer. Several leading experts on technology had asserted that American firms were not commercialising university-based technologies at a sufficiently rapid rate to maintain the nation's technological leadership. Reflecting the spirit of the times, U.S. policymakers also wished to emulate the success of Japanese firms, who had captured substantial market share from American firms in key sectors. These lawmakers wished to respond to this "Japanese challenge" by adopting two features of

Japanese technology policy: a stronger emphasis on collaborative research and government support for early-stage, generic technologies in targeted areas.[1]

As a result, several key pieces of legislation were enacted in the U.S., which resulted in a rapid rise in university-industry partnerships. The critical legislative event in this arena was the Bayh-Dole Act of 1980, which dramatically changed the rules governing university management of intellectual property. Bayh-Dole established a uniform policy across federal agencies regarding patents, eliminated many restrictions on licensing, and most importantly, allowed universities (rather than the federal government) to own patents arising from federal research grants. A second legislative initiative was the National Co-operative Research Act (NCRA) of 1984, which provided additional incentives for firms to engage in research joint ventures (RJVs), by significantly reducing antitrust penalties associated with collaborative research.[2,3]

Funding initiatives aimed at promoting technology partnerships also stimulated university-industry collaborations. The Omnibus Trade and Competitiveness Act of 1988 established the U.S. Commerce Department's Advanced Technology Program (ATP), which supports collaborative research projects on generic technologies, some of which involve research joint ventures between firms and universities. Prominent public-funded technology

[1] Such legislators insisted that such initiatives did not constitute an "industrial policy."

[2] See Link, Paton, and Siegel (2001) for additional discussion of the antecedents and consequences of NCRA. The NCRA was subsequently amended by the National Cooperative Research and Production Act (NCRPA), which was enacted in July 1993. NCRPA amended the NCRA to include joint research and production joint ventures.

partnerships in other OECD nations include the VLSI (Very Large Scale Integrated Circuit) programme in Japan and the ESPRIT (European Strategic Program for Research and Development of Information Technology) and EUREKA (European Research Co-ordinating Agency) programmes in the European Union.

During the 1980s, the U.S. National Science Foundation (a federal/national agency) also substantially increased funding for Industry-University Co-operative Research Centres (IUCRCs). IUCRCs, which depend on industry support, are designed to promote technological diffusion, commercialisation, and integration of research and education. Many universities in all OECD nations have also established science parks and incubators on or near campus, which may be viewed as another relevant type of technology partnerships.[4] These institutions often receive additional financial support from individual state or regional governments, since they are perceived as promoting economic growth and development.

A salient point regarding these technology partnerships is that they all receive some level of support from a public institution. Such assistance can assume various forms, such as government subsidies for projects funded by private firms (e.g., ATP or EUREKA), shared use of expertise and laboratory facilities (e.g., IUCRCs), and public financial support for university-based

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[3] Jaffe (2000) surveys the major changes in U.S. patent policy and practice in the last two decades.

[4] The first U.K. science parks were established by Cambridge and Heriot-Watt Universities.

institutions devoted to the creation of entrepreneurial start-ups (e.g., technology incubators and science parks).

The end result of these initiatives has been substantial growth in the incidence and scope of university-industry relationships. As a result, almost all research universities in the U.S. have established technology transfer offices (TTOs) to manage these relationships and facilitate commercial knowledge transfers. Accordingly, the number of patents granted to U.S. universities has increased from 300 in 1980 to 3,661 in 1999, while licenses have increased almost twelve-fold since 1991.[5] Membership in the Association of University Technology Managers (AUTM), an organisation of licensing officers at U.S. universities, has increased from less than 113 in 1979 to over 2,178 in 1999. Annual licensing revenue has grown from $160 million in 1991 to $862 million in 1999, now constituting about 2.7% of university R&D expenditures.

Similar increases are evident for other dimensions of university-industry technology transfer. Link (1996) reports that university participation in RJVs has risen steadily since the enactment of NCRA in 1984. Hall, Link, and Scott (2000) find that 57% of the research projects funded by ATP involved firms collaborating with universities. Cohen et al. (1998) reported that the number of IUCRCs increased by 154% during the 1980s.

There has also been a dramatic increase in university-industry partnerships within the European Union and with collaborating states. Siegel, Westhead, and Wright (2002) report that the number of U.K. university science

parks has increased from two in 1972 to 46 in 1999. Caloghirou, Tsakanikas, and Vonortas (2001) analysed 6,300 RJVs in 42 nations that received funding from the European Commission, under the auspices of the European Framework Programmes (FWPs), during 1983-1996. The authors note that almost two thirds of these RJVs involved at least one university, a percentage that has risen considerably since the funding programme began (from 56% in 1983 to 67% in 1996).

In the next section, we discuss in some detail the particular market failures that industry-university partnerships help to mitigate.

III. UNIVERSITY-INDUSTRY PARTNERSHIPS AND THEIR EFFECTS ON INNOVATION MARKET FAILURES

There are several ways for universities and firms to form partnerships. A popular mechanism for establishing such a relationship occurs when a firm contracts with university researcher to conduct R&D on its behalf. Projects of this nature tend to involve applied research or consultancy, rather than fundamental research.[6] These activities constitute a principal-agent relationship, in which all property rights are vested in the firm. Such contracts are typically of a cost-plus form, where the firm bears all the risk and the agent has weak incentives to maximise efficiency. Of course, there are other types of contracts - for example, payment by results. Such agreements may be used if the

[5] Source: AUTM (2000). See also Hicks et al. (2001) for further evidence on the growth of U.S. university patenting and its geographical distribution.

firm employs a private research contractor. Indeed, if the firm were faced with the alternative of contracting with a private research firm and a university, and if both were equally good at doing research, then it would never contract with the latter. That is because a company gets a better deal contracting with a private firm (or conducting the research internally). A firm would only use the university as a contractor if academic researchers were more proficient than industry scientists in conducting the applied research (perhaps because university scientists had conducted the underlying fundamental research) and this gain were sufficiently great to offset the negative effects of using a cost-plus contract.

At the other extreme is the case when a university researcher develops an idea for commercialising some application of his/her work and enters into a contract with a firm to do so. In this case, all the intellectual property is vested with the university and its relationship with the firm is simply to gain access to business expertise to facilitate commercialisation of the product or process innovation (e.g., pharmaceutical product). Here the university is the principal and the firm is the agent providing commercialisation services. Now the university has to bear the risk and may not be in a position to do this as a publicly-funded body. A likely result is that a spin-off company will be established and this entity will enter into a relationship with the firm. This type of partnership is not really between the firm and the university, but between the

[6] The incentives of universities to get involved in such links have been analysed in Beath *et al.* (2000).

firm and the private spin-off company and thus, will look more like a conventional research joint venture between two firms.[7]

An intermediate situation, but one that we shall argue is quite common, occurs when the university has conducted some basic research that generates new fundamental ideas. From a commercial standpoint, these ideas are still at an embryonic stage, although the fundamental work has been made available through the normal public codified channels. Unfortunately (from the firm's perspective), only a fraction of the knowledge is actually codified. The remaining fraction is tacit and can only be conveyed via direct interaction and discussion with the scientists in the university. However, the firm may only understand a fraction of this fundamental knowledge through these channels of communication, and this might be insufficient to allow it to develop the product or technology. The firm will therefore wish to employ the relevant scientists to help them understand the knowledge better so that they can then decide how best to develop this knowledge into some commercial product/technology.

In this case, all the development work is done by the firm, which bears the risk that the development project might not succeed. Hence, all property rights in the technology/product are vested in the firm. The fundamental knowledge is still freely available. All that is happening is that the university is helping the firm improve its understanding of the knowledge. However, this relationship has contractual problems. The relationship between the firm and the university cannot be handled by a contract to deliver the remaining fraction of knowledge –

[7] See Katz and Ordover (1990), De Bondt (1997) and Poyago-Theotoky (1997) for surveys of the

since the firm doesn't know what that is, it cannot contract on this. The company is therefore limited to a rather simple input contract: it pays a fee and buys specified amount of the academics' time. The firm bears the risk that (i) it still might not fully understand the idea, however well academics spell it out, and (ii) that the academics might not expend enough effort to explain it clearly. Nevertheless, both sides have an incentive to establish such a partnership.

For firms, this relationship generates two benefits: (i) the acquisition of knowledge that can ultimately generate additional profit and (ii) skill/knowledge enhancement of its own scientific workforce. As Cohen and Levinthal (1989) have explained, such alliances may significantly enhance a firm's capacity to "absorb" certain specific knowledge, as well as related knowledge emanating from other sources. The university also derives several benefits. First, the additional income can be used to enhance fundamental research (e.g., through the purchase of additional equipment or postdoctoral researchers to conduct experiments). Second, the existence of such relationships can be used to attract and retain star scientists. Finally, there may be in-kind benefits that accrue to the university from these partnerships, such as an increase in the desire of companies to employ students and additional sponsored research.

Another type of intermediate link occurs when universities and firms collaborate to develop a product or technology. In this case, inputs are required from both parties. Neither the firm nor the university can develop the idea alone. The added dimension to the case in the previous paragraph is that now

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literature on cooperative R&D amongst firms.

there is an asset – the product/technology – that is jointly produced and so could in principle be jointly owned.

As noted in Hall, Link and Scott (2001), such partnerships have become increasingly popular.[8] They assume a variety of forms, ranging from formal contractual relationships managed through Technology Transfer Offices (e.g., licensing agreements between universities and firms and research joint ventures) to more informal arrangements, such as educational partnerships (e.g. the Teaching Company schemes in the UK or, special training programmes and the hiring of graduate students) and consultancy arrangements. As reported in a recent National Academy of Engineering (NAE) study, summarised in Grossman, Morgan and Reid (2001), informal alliances are potentially crucial sources of technological spillovers. The NAE study examined the contributions of academic research to industrial performance in five major industries and concluded that in some sectors, faculty consulting and educational partnerships played a key role in the introduction of new production processes.

In view of the increasing importance of university-firm R&D partnerships and their active support by government, it is natural to ask whether they have beneficial effects in mitigating the market failures typically associated with R&D. The standard literature on this topic tends to focus on the R&D behaviour of firms and identifies a number of issues. In cases where timing matters as, for example, in patent races and waiting games, the theory suggests that will be over-investment in the former and under-investment in the latter and in both

[8] See also, Adams, Chiang and Starkey (2001) and Kaufmann and Tödtling (2001).

cases, firms may be involved in unnecessarily duplicating each other's research. Typically these firms will be pursuing substitute research paths. However, if the paths they are pursuing are complementary, then these complementarities will be under-exploited if firms are not sharing information and coordinating their R&D activities. These are all arguments in favour of research joint ventures as these internalise the externalities involved and shift the allocation of resources closer to the first best.[9] However these are arguments that one would use when considering firms. It is not clear that these arguments necessarily apply to technological partnerships between firms and universities.

In fact, there are three respects in which they are applicable. The first relates to research spillovers, the second to information asymmetries, and the third to research complementarities.

An important component of the research done in universities is driven by the desire of the individuals involved to answer fundamental questions and scientists engaged on such pursuits may not necessarily see that there are practical applications of results they obtain. As noted earlier in this section, through formal links with firms, such applications may be realised. In this sense, there is a useful spillover of knowledge from the university scientist to the industrial technologist. Since the additional gains can be shared if there is a collaborative venture, the benefits associated with any given level of scientific research effort are enhanced and more effort may be expended that would have

[9] Since the 1980's both the United States and the European Union have actively encouraged collaborative research by relaxing anti-trust laws in relation to cooperative R&D. At the same time, Japan has continued with its long-standing support of co-operative R&D.

otherwise have been the case. This is a case where a beneficial externality is perceived and exploited, something that might not otherwise have occurred.

Knowledge is a commodity in which asymmetries of information are endemic. For the buyer of a piece of knowledge, its quality may not be apparent until an attempt is made to use it. Markets in which there is this asymmetry between sellers and buyers are naturally thin and mutually beneficial transactions may be ruled out if buyers and sellers are in infrequent contact. Building relationships between universities and firms can serve to bridge this information gap and so promote the beneficial exploitation of fundamental knowledge. As indicated above, in the case of inventive ideas, a great deal of the useful knowledge may be tacit and only fully appropriable, either through the efforts of the person holding the knowledge or through close and easy interaction between that person and those who could potentially use it.

Some innovations of a generic sort are best viewed as creating intellectual human capital and are characterised by a natural excludability, as opposed to a set of instructions for combining inputs and outputs that can be protected only by intellectual property rights. The natural excludability arises either from the complexity or from the essentially tacit nature of the information required to make effective use of the innovation. Zucker *et al.* (1998) have argued that this describes the nature of innovative activity during the first 10-15 years of the biotechnology industry. Specifically, the authors assert that there was a naturally excludable knowledge base held by "a small initial group of discoverers, their co-workers, and others who learned the knowledge from

working at the bench-science level with those possessing the requisite know-how."[10] Eventually it became part of "routine science". The primary pattern in the development of the industry was one of scientist-entrepreneurs who knew how to do recombinant DNA. Few of these academics were willing to give up their university affiliation – perhaps for reasons of status, risk aversion, or for signalling reasons - and laboratory teams. Thus, they remained on the university faculty while establishing a business on the side.

When universities and firms collaborate, they may be able to exploit complementarities. Companies are focused on commercialising university science, by transforming the scientific knowledge base into useful goods for which there is a market. University scientists, on the other hand, are typically highly specialised researchers and do not possess the requisite skills to transform knowledge into useable technology and/or intermediate or final goods. On the other hand, firms should, by definition, possess specialised skills for commercialisation. Joint ventures or partnerships between universities and firms can exploit these complementarities, again to mutual advantage. Another example occurs when complementary equipment and facilities enable the scaling-up of a new process from experimental to commercial to assess its market feasibility.

In addition to these general arguments, we also wish to examine precisely how such formal links between universities and firms mitigate market failures. A recent paper by Jensen and Thursby (2001) is quite useful in this regard.

[10] Zucker *et al*. (1998), p. 291.

Based on a survey of 62 universities, the authors report that the vast majority (77%) of university-based inventions required some inventor involvement in development. For example, 48% of their sample reported that the innovation was simply at the "proof of concept" stage, with no prototype, and a further 29% had only reached the stage of a laboratory-scale prototype. Thus once a licensee is found, most university inventions require further development. The empirical evidence also indicates that efforts by licensees to develop embryonic inventions alone are unlikely to succeed. In 71% of the reported cases successful development of the invention required cooperation by the inventor and the licensee in that further development work.

To clarify these issues, we now present a formal analysis of the problem.[11] Suppose that the embryonic invention with suitable and successful development has a value V. However, to realise this requires investment in effort by both the scientist (denote this by e) and by the company (denote this by E) that acquires it.[12] The probability that these efforts will lead to a successful outcome can be written, without significant loss of generality, as

$$p = q(e) + r(E),$$

where (i) $0 \le p < 1$ and (ii) q and r are functions that have diminishing marginal return to effort. The first best solution involves jointly choosing the effort levels

[11] The analysis draws on Aghion and Tirole (1994).
[12] For present purposes we can think of e and E as being measured in monetary terms.

e^* and E^* to maximise the net return to undertaking the development of the project. The optimal levels of effort are where, for each party, the marginal return to effort equals $\left(\frac{1}{V}\right)$ and are illustrated in Figure 1.

(Insert Figure 1 about here)

If the university licenses this invention to the firm at a fee L (< V), this results in under-investment. The university scientist has no incentive to devote more effort and thus, sets e = 0.[13] The firm sets its effort level at $\bar{E}$ where the marginal return to effort equals $\left(\frac{1}{V-L}\right)$. Clearly $\bar{E} < e^* + E^*$: there is under-investment. If the university and the firm form a partnership for the development of the invention, V will be shared. On the assumption of contractual incompleteness, the sharing rule cannot be conditioned on the effort levels e and E. Thus we shall consider this to be established by ex-ante bargaining in which, for the sake of argument, each obtains $\left(\frac{V}{2}\right)$. The fact that there is now an incentive for the scientist to put in effort will get us away from e = 0. In fact the equilibrium effort levels will be defined by the condition that the marginal return to effort is equal to $\left(\frac{2}{V}\right)$. Denote these effort levels as $\hat{e}$ and $\hat{E}$. There is still under-investment, for $\hat{e} + \hat{E} < e^* + E^*$; however is it the case that

$\hat{e}+\hat{E}>\bar{E}$? Well, for incentive compatibility reasons L has to be less than $\left(\frac{V}{2}\right)$ so that $\left(\frac{1}{V-L}\right)<\left(\frac{2}{V}\right)$ and hence $\hat{E}<\bar{E}$. So the partnership will improve aggregate effort only if $\hat{e}>\bar{E}-\hat{E}$. While one cannot guarantee this is the case in such a general set-up, it seems likely that this condition would hold and so we can see why it is that this partnership arrangement can attenuate, though not eliminate, the market failure of under-investment.

If investment and timing are positively correlated, the existence of such university-firm linkages implies that the final product or process will reach the market sooner. Simply put, university-industry partnerships appear to accelerate technological diffusion. This findings has important policy implications, since it confirms the logic of the framers of the Bayh-Dole legislation in the U.S., who asserted that university ownership and management of intellectual property would accelerate commercialisation.[14] With this result in mind, it is not surprising to observe the formulation of policies that stimulate the formation of university-industry partnerships. Thus, in July 2000, the UK government in setting out its policy for Science and Innovation in the White Paper (titled *Excellence and Opportunity*), committed itself not only to funding basic research but also to encouraging knowledge transfer and the effective

[13] Since effort is unobservable, it cannot be contracted on and so our analysis involves incomplete contracts.
[14] See Siegel, Waldman, Atwater, and Link (2002).

exploitation of knowledge and new technology.[15] Given the growing incidence and scope of industry-university partnerships, we discuss their benefits and shortcomings in the next section.

IV. TRADE-OFFS ASSOCIATED WITH AN INCREASE IN UNIVERSITY-INDUSTRY PARTNERSHIPS

Table 1 summarises the benefits and potential drawbacks of an increase in university-industry partnerships. Such alliances can potentially generate positive private and social returns. Private returns refer to direct sources of revenue to the university, from licensing and equity income, and indirect revenue sources, such as sponsored research, donations, and in-kind support from companies.

Beath et al. (2000) examine the critical issue of how universities should determine the optimal level of "taxation" of research consulting agreements between academics and firms. Their model assumes that universities undertake fundamental research with financial support from public agencies, which has been dwindling in recent years in the U.S. and E.U. To ease funding pressures, university scientists can undertake research for industry, which can simultaneously benefit the university, by suppressing academics salaries or increasing revenue through the imposition of "overhead charges". This may enable universities to hire more scientists, resulting in an increase the stock of

[15] It is seeking to encourage the commercialization of university research through things like the University Challenge Fund, Science Enterprise Centres and the HE Innovation Fund. These

fundamental knowledge. Society may also be better off, given the public good properties of knowledge. That is, the resulting expansion in fundamental research by universities is likely to raise the productivity of applied research in the private sector, which could generate higher productivity growth (Lichtenberg and Siegel (1991)).

It is conceivable that universities can also benefit from "reverse" technology transfer (i.e., technology transfer that flows from firms to universities), enabling academic scientists to conduct better experiments, as a result of their interactions with industry scientists.[16] These alliances may also have a positive effect on the curriculum, as faculty members draw on their experiences with firms to provide instruction that is more relevant and more closely aligned with the needs of high-technology firms (see Stephan (2001)). Positive social returns could also arise from more rapid technological diffusion, resulting in an acceleration in the rate of development of new products and processes, the creation of new firms, and enhanced economic development.

Richard Nelson (2001) argues that a major drawback of greater commercialisation of university research is its potential degradation of the culture of "open science" (Dasgupta and David (1994)) that permeates institutions of higher learning. Open science refers to the free exchange and dissemination of new ideas among faculty members and students. Such concerns were magnified in the aftermath of a landmark event in the annals of university-

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funds are to be used in conjunction with Regional Development Agencies to support clusters and incubators and "clubs".

[16] See Siegel, Waldman, and Link (1999) for some anecdotal evidence supporting this assertion.

industry technology transfer: the 1998 strategic alliance between the Department of Plant and Microbial Biology at the University of California at Berkeley and Novartis, a Swiss life sciences and pharmaceutical firm. This alliance grants first rights to Novartis to negotiate licenses on approximately one third of the department's inventions for the next five years. Press and Washburn (2000) note that some were concerned that Novartis would attempt to influence the department's research agenda, since the Berkeley administration permitted the company to have two of the five seats on the committee that decides how research money is spent.

Alliances of this sort are highly controversial in biotechnology, where there are especially close linkages between agribusiness firms and universities. Indeed, some observers have noted that in this field, such partnerships may be required for institutions that wish to remain at the cutting edge of research. This has caused significant consternation to those opposed to the proliferation of genetically modified foods and those who assert that the presence of private firms at universities will alter the behaviour of academic scientists.

In this regard, several authors have examined changes in faculty behaviour in the aftermath of their involvement in commercialisation activities. Louis et al. (2001) find that academic scientists engaged in entrepreneurial activities are more likely to deny requests from fellow academics for research results than other faculty members who are not engaged in entrepreneurial activities. This result is consistent with Blumenthal et al. (1996), which reported that faculty members with industry support are more secretive regarding their

research findings than faculty members without such industry support. Although this finding should be interpreted with caution, since it could reflect selection rather than causation, it does at least imply a positive correlation between industry funding and secrecy.

Another open science concern relates to database protection and access. Recent legislation in the E.U.[17] has introduced *sui generis* protection on any collection of information (databases) from unauthorised copying, while at the same time urging the U.S. to enact similar legislation or face retaliation. This has sparked controversy regarding the potential difficulties associated with the use of information contained in databases for the advancement of science, especially in biotechnology and biomedicine, gene-mapping and bio-informatics (Gardner and Rosenbaum (1998), Maurer and Scotchmer (1999)).[18] The database protection issue could possibly lead to what Heller and Eisenberg (1998) refer to as an 'anti-commons' problem, i.e., a situation where it becomes increasingly difficult to assign intellectual property rights to all of the parties involved in creating a database. These co-ordination difficulties create a scenario where it is highly likely that scientists will have fewer incentives to use the database for additional research, thus hampering the advancement of knowledge. University-industry partnerships in this area can potentially serve to resolve the conflict between the culture of "open science" and the commercial exploitation of a database, in the same manner that commercialisation of embryonic inventions

[17] European Union Council Directive 96/9/EC.
[18] At the time of writing, it is not known whether the U.S. will pass similar legislation (Maurer, Hugenholtz and Onsrud (2001).

has generated increased basic research.[19]

Another critical policy issue is whether university-industry partnerships encourage a shift from basic to more applied research by academic scientists. Interestingly, some preliminary evidence appears to contradict the conventional wisdom that university technology transfer reduces the quantity and quality of basic research performed by academics. Zucker and Darby (1996) report that "star" scientists in biotechnology had excellent research performance after becoming involved in commercialisation and patenting. Similarly, Louis et al. (2001) find that entrepreneurial faculty members have higher scholarly productivity than non-entrepreneurial faculty. These findings are consistent with field evidence presented in Siegel, Waldman, and Link (1999), which reported that faculty members involved in commercialisation projects typically re-invest their "profits" in laboratory equipment and additional postdoctoral researchers, enabling them to conduct additional experiments.

Furthermore, Stephan (2001) asserts that university-industry partnerships could have negative effects on education, including the content and quality of teaching, and faculty-students relationships. One concern is that faculty members involved in commercialisation activities may spend less time on teaching and service. Alliances with industry may also shift attention away from fundamental research questions that do not appear likely to generate a commercial payoff. Additional secrecy may also have a deleterious effect on

[19] Maurer (2001) vividly describes the case of the Mutations Database Initiative (MDI) – a worldwide organization of academic scientists - and Incyte in their (failed) attempt to commercialize human mutations data.

relationships between faculty mentors and graduate students by creating conflict and diminishing trust between advisor and student. Such conflicts have recently been reported at Chicago, Columbia, and Cornell Universities (Marshall (1999), (2000)) where graduate students have initiated litigation against their respective advisors and universities. Thus far, the courts have decided in favour of the universities and there is no systematic evidence that these universities have been hampered in their efforts to attract and retain graduate students.

V. CONCLUDING REMARKS

Our review of the extant literature indicates that we still know very little about the global impact of the rise of university-industry partnerships. Theoretical studies suggest that these alliances are needed to address innovation market failures, especially those relating to basic research. Unfortunately, there is a paucity of empirical evidence on this topic, primarily because data limitations preclude an accurate assessment of the private and social returns to these activities.

We have reason to be optimistic that more precise empirical evidence is likely to be available in the near future, given the trend towards greater scrutiny of public investments in R&D. As described in Link and Scott (1998), this stems, in part, from recent initiatives to hold public technology-based institutions more accountable for documenting the economic impact of the partnerships they have financed. Indeed, some qualitative evidence from the U.S. ATP Program (Wessner (1999)) implies that the social returns to RJVs involving universities

and firms are quite high. Still, we need more systematic econometric studies for a wide variety of programmes in different nations.

In order to have a better understanding of the trade-offs involved in greater commercialisation, we need further research on the antecedents and consequences of changes in faculty behaviour. This includes questions regarding the impact of partnerships on the quantity and quality of basic research, the culture of open science, and education.

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Table 1

Trade-offs Associated With An Increase in University-Industry Partnerships

Benefits	**Drawbacks**
Additional Revenue for the University	Negative Impact on Culture of Open Science
More Rapid Technological Diffusion	Negative Impact on Student/Adviser Relations
Choices Regarding Technological Emphasis	Could Reduce the Quantity and Quality of Basic Research
Positive Effects on Curriculum	Negative Effects on Curriculum
Local/Regional Economic Development	Could Affect Types of Research Questions Addressed
Two Way-Knowledge Transfer	Academics Could Spend Less Time on Teaching and Service

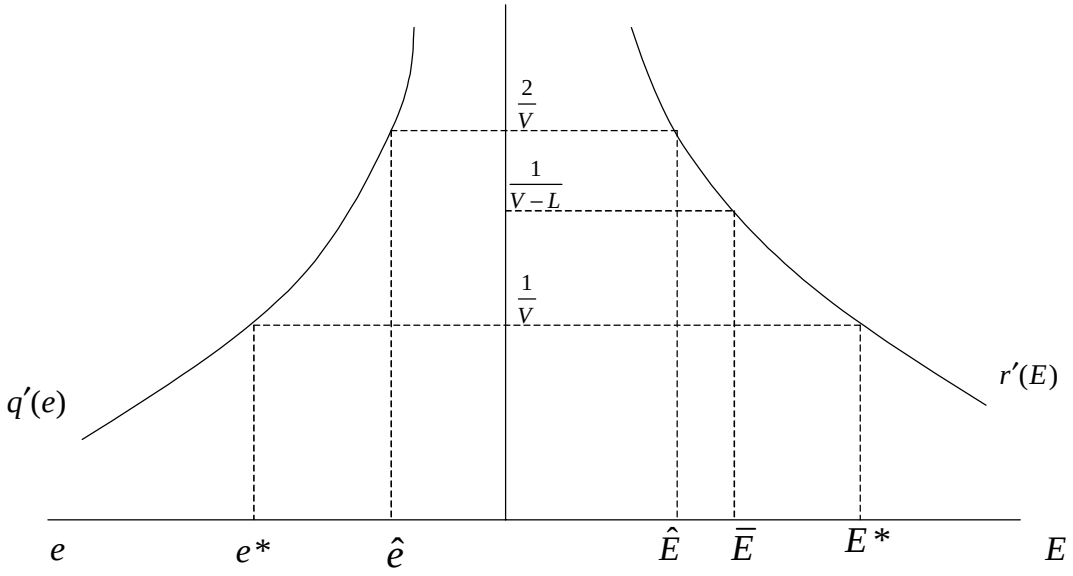

Figure 1