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Bottom-Up vs. Top-Down Policies towards the Commercialization of University Intellectual Property*

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Abstract: What national policies are most efficient in promoting the commercialization of university-generated knowledge? We address this question by characterizing and evaluating the policy pursued in Sweden and the US, two countries that put a great deal of resources into university R&D, but follow very different models for commercialization. Despite a leading academic record, there is an impression of laggard rates of commercialization of academic research results in Sweden. Although there exist no micro data to evaluate this impression, we argue that it is likely to be true in part due to the top-down nature of Swedish policies aimed at commercializing these innovations as well as an academic environment that discourages academics from actively participating in the commercialization of their ideas. This sits in stark contrast to a US institutional setting characterized by competition between universities for research funds and research personnel, which in turn has led to significant academic freedoms to interact with industry, including significant involvement in new firms.

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1. Introduction

Today, the commercialization of university-generated knowledge looms large in the public discussion. This is natural given the recent scientification of technology in key industries. Since a large share of the production of scientific results takes place at universities, the interface between universities and industry has come into focus. Policymakers in many developed countries have responded by erecting extensive infrastructures intended to facilitate the commercialization of scientific research output. This paper identifies two central strategies, and the incentive structures that they create. We then consider which set of policies are most effective. Following Nelson and Rosenberg's (1993) methodology for comparing national innovation systems, we compare subsets of the U.S. and Swedish innovation systems that affect the commercialization of university technology. As this methodology does not provide a means to evaluate the efficiency of different national policies, our study is highly exploratory and our conclusions only suggestive. However, this caveat does not make such studies less urgent. In this study we will evaluate two national policies towards the commercialization of university intellectual property, namely, the United States and Sweden. The U.S. model is very much focused on creating (economic) incentives for universities to commercialize their research output and then allowing them to experiment to find the best means by which to do that. In contrast, the Swedish model, which is similar to most European Union countries' models in some respects, is very much an attempt by the government to directly create mechanisms that facilitate commercialization. Indeed, our findings are echoed in the results of parallel research conducted by Gittelman (2002), who reaches conclusions similar to our own.

Measured by per-capita publication measures, Sweden is an academic powerhouse. In some subfields this translates into significant amounts of academic output on absolute levels as well. Because of data constraints, it is difficult to detect transfer of university inventions in Sweden. Although it is unclear if this reflects a lack of transfer in general or simply a data problem, it is evident that Sweden's transfer performance through one mechanism, the small start-up firm, is weak. An important clue to this puzzle comes from a growing body of evidence that the role of academics in commercializing their discoveries is critical. This paper compares the different incentive structures that academic researchers face in the United States and Sweden and demonstrates that in Sweden academics face strong disincentives to take the time away from their academic pursuits to facilitate knowledge transfer to the commercial sector. This problem is likely to be especially important when the optimal mode of transfer is through new start-up firms. We do not claim that there is conclusive evidence that the Swedish technology transfer programs are a failure. However, in light of our analysis we believe that it is unlikely that Sweden is harvesting the full commercial potential of its research output as successfully as the U.S.

Surprisingly, we find suggestive evidence that the American university system, whereby intellectual property is commonly awarded to universities, is more effective in facilitating the commercialization than the Swedish system in which rights are awarded directly to the inventor. That is, in order to understand the incentives created by intellectual property rights, it is imperative to understand the larger institutional context.

It is important at this early stage to define the domain of our analysis. There are a plethora of mechanisms for technology transfer (Sandelin, 2001). Graduate students regularly carry knowledge from the Ivory Tower into other sectors. Publications and conferences permit industry to monitor and exploit new knowledge produced at universities. Faculty consulting leads directly to the transfer of knowledge. Whereas visiting scholars have long allowed academics from different institutions to exchange knowledge, more recent constructs such as industry affiliate programs, research collaborations and interdisciplinary research centers have brought industry representatives onto campus for similar purposes. Technology licensing is a mechanism that has expanded greatly in the US since the Bayh-Dole act of 1980. The analysis of all these mechanisms is well beyond the scope of this study. Instead, this analysis will focus on these mechanisms insofar as they facilitate the transfer of *novel* ideas over which intellectual property rights can be established.

A further qualification is perhaps in order. In the exercise that follows, we attempt to establish that Sweden, a country with half the population of Greater Los Angeles, is unsuccessful in commercializing university technology due to an incorrect incentive structure. We do this by comparing its relative performance with that of the United States. One might expect that a country so small cannot reasonably be expected to produce enough commercially valuable knowledge to have any substantial commercialization activity simply because the supply of ideas may be too low. We cannot directly evaluate the strength of this claim because it is unknown at what levels of academic output, as measured by publications, one might expect to see substantial levels of commercialization activity, even if we could agree on exactly what is meant by substantial. To deal with this challenge, we offer some evidence that academic output in commercially relevant fields such as biotechnology is large, even on an absolute scale. Second, as we argue below, we feel that it is likely that by correcting its incentives, Sweden could be reasonably expected to improve its performance in commercialization.

Recent surveys of Technology Licensing Offices (TLOs) in U.S. universities have revealed an important finding in the American experience that may be directly relevant to the modest Swedish achievements in technology transfer: commercialization of university ideas generally requires the continuing involvement of academic inventors (Jensen and Thursby, 2001). In the U.S., the competitive nature of the university environment, along with legislation such as the Bayh-Dole Act, which gave universities title to innovations that took place inside their walls, have caused universities to adopt policies to encourage, or at least to permit, the continuing involvement of academic researchers, thus facilitating the transfer of ideas to the private sector.

The Swedish experience is quite different. The Swedish government has invested lavishly in university research that has, in turn, produced impressive *academic* results. At the same time, it has enacted an extensive set of policies to facilitate the transfer of these results to the commercial sector. Unfortunately, this effort has largely failed to create incentives for academics to remain involved in the commercialization of their ideas. Not only have Swedish academics historically faced limited potential upside gains to entrepreneurial ventures, but the policies have not succeeded in limiting the downside risks vis-à-vis the inventors' academic careers. A key problem has been the failure to provide universities with incentives to encourage commercialization of academics' ideas.

It should be understood that we are not recommending, in what follows, that Swedish universities treat American arrangements as a role model, especially insofar as that model implies the suppression of some traditional academic norms. Rather, we invoke the American experience for the insights that it may provide for Sweden's achievements in transferring technology from its universities into various sectors of the economy. We also believe that there are many similarities between the Swedish university system and those of continental Europe, inasmuch as their universities are essentially parts of larger national bureaucracies and therefore compete with one another to only a rather modest degree. We suggest, then, that the conclusions that we draw from our analysis may also be applicable, at least in part, in a larger European context.

The paper proceeds as follows. In section 2 we review mechanisms commonly used in technology transfer. In section 3 we examine incentives to exploit these mechanisms in the US and in section 4 we repeat the exercise for Sweden. Section 5 compares the rate and success of commercialization in both countries. Section 6 examines possible differences in the supply of ideas. Section 7 frames the results in a larger institutional setting and section 8 concludes.

2. Commercialization of Academic R&D – Methods of Technology Transfer

An overriding fact that has significant bearing on our conclusions is the following: *The transfer of knowledge from the university to the commercial sector generally requires the active involvement of university inventors.*[1] In the US, ideas reach TLOs in primitive states and much critical knowledge is often tacit. In one survey, Jensen and Thursby (2001) find that at least 71 percent of inventions require further involvement by the academic researcher if they are to be successfully commercialized. 48 percent of the ideas are in proof of concept stage, 29 percent have a prototype available on a lab scale and for only 8 percent is manufacturing feasibility known. The choice of instrument to facilitate academic involvement must balance two central forces. On one hand, we should expect different mechanisms to be most appropriate for transfer in various settings. On the other hand, further involvement of the researcher may have a significant opportunity cost as there is little reason to believe that activities facilitating commercialization also forward an academic's professional reputation. We first focus on the latter claim, by considering the incentive structure normally faced by academics. We then consider different mechanisms for technology transfer and discuss the advantages and disadvantages of each.

[1] For some examples of this, see Gelijns and Rosenberg (1999).

The academic reward structure encourages the production of knowledge that is a useful input into other academics' research.[2] Researchers wish to have their papers cited because this is a signal that they have established a reputation within the academic community. There is much evidence suggesting that the production of such knowledge is a central objective of academic researchers, as citation measures are associated with higher income and prestige (Cole, 1978; Diamond, 1986; Dasgupta and David, 1994; Stern, 1999). This presents a potential difficulty in the commercialization of university ideas. There is little reason to believe that the goal of producing useful inputs into the research of other academics is congruent with the goal of producing commercially valuable knowledge. Hence, effort directed at the production of commercially valuable knowledge will most likely come at the expense of the production of reputation-enhancing academic knowledge.

Of course, this is not categorically true. As Rosenberg (1982) and Stokes (1997) have argued, there are many instances where academically valuable results can emanate from research with practical goals and vice versa, commercially valuable knowledge can result from research with very academically-oriented goals.[3] In addition, there are many cases when the output of such research endeavors can be characterized as both commercially valuable and important from an academic viewpoint. Recombinant DNA is a classic example and the transistor effect is another. However, it would be surprising if this were the norm, rather than the exception. For example, Goldfarb (2001) provides statistical evidence that the pursuit of practical goals is unlikely to be congruent with the pursuit of academic goals. Because of this, research sponsors with applied goals in mind have difficulty building relationships with high-profile academics. Goldfarb's study focuses on academic engineers, a field where one might expect a goal conflict to be prominent. However, even in biotechnology, a field where commercially valuable knowledge and academically valuable knowledge are perhaps uniquely close, there can still be conflict. According to one observer,

> "I have recently visited a major teaching department in biophysics and molecular biology… with a distinguished record in Ph. D. production. The faculty who had

[2] The following discussion on academic goals draws heavily on Goldfarb (2001).
[3] There is certainly great overlap between commercially valuable and practical knowledge. Although, there are exceptions. Consider the following case: a biotech firm with little more than an idea could be sold, and hence be commercially valuable, but the idea may yet be far from practical. But even here such knowledge has the potential to be useful in the foreseeable future. And if the idea originated from a university, its commercialization would likely require the inventor's continuing involvement.

> commercial affiliations had a particular charm for incoming graduate students… The dissertations … which were being handed out, had deteriorated in quality and some of these were purely developmental product-oriented studies of little basic importance."
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> --- D. Stetten Jr., "Recombinant molecules: Anxieties and Hazards." In Proceedings of the 1981 Battelle International Conference on Genetic Engineering, Vol 1., held in Rosslyn Virginia. June 6–10, 1981. pp. 63–64. Quoted in Kenney (1986, p. 117).

The incentive structure of academics does not encourage commercialization activity. If anything, such activity is generally discouraged as it diverts effort from more fundamental research endeavors. Hence, because successful technology transfer requires the involvement of faculty, and this involvement will often continue after the academic value of an innovation has been exhausted, *the creation of incentives and the weakening of disincentives for the academic to direct effort towards commercialization activities is generally necessary for technology transfer*.

We now focus on two groups of mechanisms. Three mechanisms that are commonly used to elicit involvement in a project of commercial value are sponsored research, consulting (including board activities), and starting a new firm. Three possible mechanisms of inventor compensation are salary, royalties and equity. These mechanisms are distinct from incentives associated with the academic reward structure described above, in that they are specifically designed to facilitate the transfer of commercially valuable knowledge. We will now discuss these mechanisms in detail.

Survey results suggest that the form of inventor involvement most preferred by academics is research grants whereby the researcher continues research in her lab that is relevant to the commercial endeavor (Jensen and Thursby, 2001). Generally, there are special provisions that allow the sponsor to extract rents from the potential results stemming from sponsored research. This arrangement allows the researcher to hedge the downside risk of lost academic opportunity which occurs if commercial pursuits are not aligned with academic pursuits and time is allocated towards the new venture as opposed to academic research. One might think that corporate-sponsored grants in themselves divert effort away from "pure" academic research. Indeed, the results of Goldfarb (2001) suggest are consistent with this theory. However, although research that is industry-funded is clearly directed, researchers' effort allocations are arguably less constrained in a grant arrangement than when they are directly involved in a company as consultants, board members and/or founders.[4] Although this sort of research support provides weak incentives, it is likely to be inexpensive. Furthermore, it may be appropriate in the very early stages of research, or when sponsors believe that clauses which allow them to examine results prior to publication along with intellectual property protection of results are sufficient to provide rents from the research results. When knowledge is very tacit, we would expect this arrangement to be insufficient; the academic may not have sufficient incentives to effectively communicate results to the sponsoring firm as such activities take away from the pursuit of academic results. In such cases, we might expect this mechanism to be complemented by other mechanisms, such as consulting.[5]

The second mechanism is consulting arrangements whereby the researcher either spends a limited amount of time working for the firm and/or takes up a position on one of the firm's boards. Academics are often compensated quite generously for such activities. Consulting has a long tradition and most administrators have supported, or even encouraged, such activity. Although there are numerous policies designed to regulate such activities in the US, they are notoriously difficult to enforce (see Kenney, 1986, pp. 90–92).

Finally, the academic may found a new firm. When academics found firms this does not necessarily imply that they leave their academic positions permanently, nor take a leave of absence. Interviews with Stanford Office of Technology Licensing personnel[6] as well as case studies (Kenney, 1986) suggests that frequently an academic will take up a consulting position as well as a board position with the firm while a graduate student or post-doctoral research associate will fill more active roles in the new firm. However, even when the academic does take a secondary position, this arrangement remains distinct from consulting in that a founder will generally have a significant equity position in the new firm.

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[4] The proposition that researchers can and do substitute effort allocations is reflected in the spread of conflict of interest policies. For example, some universities, such as Stanford, do not allow recipients of grants to hold an interest in the company that is sponsoring them. The reason for this restriction is specifically to avoid turning a lab into an outsourced research arm of the sponsoring firm at the expense of academic pursuits. This policy would not be necessary if academic and commercial goals were aligned.

[5] Another shortcoming of such as distributive research effort might be in coordination of research direction. This would be particularly true if the output of the research was expected to fit into a larger system (Monteverde and Teece, 1982).

[6] Informal discussions between Brent Goldfarb and Stanford OTL personnel, May–June 2001.

The first form of academic remuneration is wages. This mechanism provides the weakest incentives to the academic to further the commercialization of the invention, as rewards are not formally tied to the outcome of the venture.[7] Two alternatives are more successful to this end: (i) providing some sort of performance based payment structure, such as licensing royalties, or (ii) equity compensation. Jensen and Thursby (2001) demonstrate theoretically that while both equity and licensing solve the moral hazard problem, equity does not affect marginal costs, and hence does not distort output decisions.

We would expect incentives in consulting to be weaker as compared to royalties or equity in that returns are not tied directly to outcomes.[8] When knowledge is largely tacit, as is common in primitive technologies, significant academic effort is likely to be required for success in commercialization. As we have argued, commonly, directing effort towards the development and commercialization of such technologies provides fewer academic rewards than the development of new academic results. Hence, high-powered incentives which directly tie results to compensation will be a more effective tool to elicit academic effort in such cases while consulting alone may be insufficient for transfer. However, this reasoning does not allow us to understand when equity versus royalty compensation is used. It should be noted that when academic involvement is needed, equity and royalty compensation is commonly used in conjunction with consulting, or salary compensation. That is, performance based compensation mechanisms generally strengthen incentives provided in consulting arrangements.

Royalty arrangements only work if intellectual property rights can be asserted. Although our understanding of when and in which combinations each of these mechanisms is chosen in incomplete, there are some clues. Arora (1995) demonstrates that if property rights are weak and knowledge is tacit the inventor will have little incentive to transfer knowledge as she is likely to be held up.[9] This result suggests that when knowledge is tacit and property rights are weak, the best means to provide incentives to the academic researcher is via equity, which becomes an especially powerful incentive in a young,

[7] One could imagine an implicit contract whereby successful consulting leads to successive arrangements.
[8] Of course, this is attenuated with the implicit contract possible in a dynamic setting where future consulting income is contingent on good performance.
[9] Held up in the sense that the firm will not compensate the inventor once tacit knowledge (see also Anand and Galetovic, 2000). The holdup problem can also be resolved if the potential licensee and the inventor have developed a relationship and both expect to continue this relationship into the future.

small company. We also know that the effectiveness of patent protection varies by industry (Cohen *et al*., 2000). We should expect, then, that all things being equal, academic entrepreneurship is more important in industries where property rights are weak, (say, semiconductors) and less important in areas where patent protection is strong (say, pharmaceuticals). Indeed, if intellectual property protection is particularly weak, we might expect transfer to occur via consulting arrangements and by-pass the TLO altogether.

Shane (2001) finds evidence consistent with this thinking. When patent protection is weak, TLOs are more likely to license inventions to the inventor. Generally, this involves licensing the invention to a new startup, or in the language of the Swedish studies, to a university spin-off. Because of the primitive nature of the technology when these firms are founded, the risk is considerable (Rosenberg, 1996). Di Gregorio and Shane (2000) find that universities are more likely to produce spin-offs if they are willing to make equity investments in new firms in lieu of royalty agreements. This solves two problems. On one hand it shifts some risk from the new firm to the university, as some royalty payments are often required before any revenues are produced and second, it attenuates some of the problems new firms face with liquidity constraints.

Our theoretical discussion also suggests that high powered incentives should be used when knowledge is tacit and inventors' opportunity costs are high which we might expect if they are academically talented. This complements results of other researchers who have distinguished between royalties and equity. Shane (2001) finds that equity is likely to be more effective if royalty arrangements are less feasible, while Jensen and Thursby (2001) theoretically demonstrate that equity is more efficient. Of course, the effectiveness of commercializing through a new startup is also limited when there is great importance of complementary activities. For example, a small company is unlikely to be able to move a drug through clinical trials (Teece, 1986). However, the proliferation of startups in biotechnology, a field where academic entrepreneurship is especially important, suggests that this is not necessarily a binding constraint.

Ideally, we would now assess and compare the use of the above mechanisms in Sweden and the US. Unfortunately, the data that relate to commercialization are incomplete. For example, we know of no systematic data that describe consulting arrangements between academics and industry, let alone data that describe how consulting is used together with licensing arrangements. While there are data that describe university spin-offs in Sweden, we have not encountered comparable comprehensive data for the US. And while there are data describing licensing activities in the US, there are no data describing such activities in Sweden. This effectively limits our ability to make direct comparisons of the Swedish and American experiences. Instead, we pursue the following strategy: we will first compare the institutional setting and their resulting incentive structures in both countries, insofar as they pertain to the commercialization of intellectual property. We will then examine data, however imperfect, to explore whether they are consistent with our conclusions about the different incentive structures.

3. The American System

The extent to which the above mechanisms are available and used within the U.S. university system varies greatly. It is likely that the broader the menu of options is in any given case, the easier it will be to fit the instrument to the technology and the more probable that an invention will reach its full commercial value. The Federal government has actively pursued policies aimed at facilitating this commercialization. Most importantly, the Bayh-Dole Act allowed universities to appropriate the property rights to an invention resulting from university research that was financed by federal grants.[11] This Act was later expanded by public law 98-620. The fact that property rights were awarded to the universities rather than the inventor gave strong incentives to universities to set up their own offices of technology transfer that have become instrumental in negotiating the appropriate mechanism for commercialization.[12] This US policy can be characterized as one that gave universities incentives to respond to a commercial opportunity, but did not dictate or even suggest what the best response to this opportunity was. The Act fostered

[11] An explicit aim of the legislators was to keep the government out of the commercialization process (Eisenberg, 1996).

[12] The Bayh-Dole Act has a small business bias, in that small firms are to receive preference over large firms when licensing decisions occur (37CFR 401.14, k.4). While we do not know how this clause is implemented in practice generally, from examining marketing and licensing decisions at Stanford's Office of Technology Licensing, it is clear that this consideration takes a secondary place to the goal of finding a firm that is capable of commercializing a new technology. Most importantly, in no way does a small firm imply a start-up firm. In fact, it is Stanford's policy to market new technologies to well-established firms, large or small, before startups in the belief that established firms are more likely to succeed in commercialization.

and continues to foster much experimentation in university policies with respect to how to best exploit this windfall of intellectual property.[13] This is a "bottom up" approach.

The bottom up approach reaches well beyond government policy. The structure of the American university system is favorable towards such institutional experimentation and competitive forces have led universities to adopt policies that encourage commercialization of ideas. For example, American universities compete intensely for financial support to push out the envelope of research frontiers in disciplines that have come to produce useful knowledge. In recent years this has most notably been the case in microelectronics, computer science and molecular biology. This competition for funds has encouraged universities to accept grants from industry that restrict access to results stemming from sponsored research, even though this is a policy that directly conflicts with well-established academic norms. An additional important dimension of American academic competition is reflected in a high degree of mobility on the part of faculty as universities compete for talent and prestige. As the commercial value of faculty inventions and services has become apparent, the demand for those services, especially those of highly reputable scholars, has increased. In response, universities have adopted policies needed to keep or attract these scientists. These policies include more liberal leave of absence and consulting privileges that generally allow the academic to pursue his commercial opportunities, while keeping his position as a faculty member intact (Kenney, 1986). Although there are potential benefits to such policies for the university, there are also obvious costs. It is unlikely that such policies would have been adopted in a non-competitive system (Rosenberg, 2000).

It might be surprising that we are arguing that awarding property rights to the university, as opposed to the inventor, has successfully increased the incentives of inventors to commercialize their activities. However, rewards are tied to project value as universities have found it best policy to reward inventors, along with departments and schools with

[13] The effect of the Bayh-Dole Act on the commercialization of ideas of university researchers is a prominent question for students of the university-industry interface (Henderson, Jaffe and Trajtenberg, 1998; Mowery, Nelson, Sampart, and Ziedonis, 2000; Mowery and Ziedonis, 2000). For example, Mowery and Ziedonis (2000) find that although the Act encouraged the establishment of technology transfer offices and coincided with a significant increase in university patenting at Stanford and within the UC system, they argue that much of these activities would have occurred without it. They find that much of the increase in university licensing can be attributed to the rapid growth in federal funding of biomedical research from 1960–1980 and other changes in federal policy toward intellectual property rights. This suggests, perhaps, that Bayh-Dole was not an exogenous event, but rather reflected changing goals of universities.

shares of proceeds from an invention.[14] Generally, universities also deduct funds to recover expenses associated with licensing activities.[15] Hence, awarding property rights to the university accomplished two goals. First, it encouraged the establishment of hundreds of offices of technology transfer at universities. These offices relieve inventors from a need to develop expertise in the legal and business sides of invention commercialization. Second, since the offices typically cover expenses associated with marketing, patenting, and licensing, inventors avoid the risk associated with covering such costs. Not only are such activities expensive, but they are also time consuming. This implies that inventors would incur substantial opportunity costs if they were to engage in such activities. When these costs overwhelm the (additional) expected returns the inventor would have earned had he had 100 percent of the intellectual property rights, commercialization becomes more likely when rights are assigned to the university.

Of course, it is not necessarily the case that only university-run transfer offices could provide these cost-reducing services whereas a private provider could not. There do not seem to be compelling reasons that would rule this solution out.[16] However, as an empirical reality private organizations have not filled the void in Sweden. This leaves Swedish academic-entrepreneurs with the costly option of going it alone.

TLOs solicit invention reports from faculty inventors. Although faculty are often required to complete these reports on a regular basis, it is often quite difficult to enforce this policy. Nevertheless, recent work that has focused on the effects of the Bayh-Dole act attribute a large share of increased patenting and licensing activities to successful identification of inventions of potential commercial value and their development rather

[14] Di Gregorio and Shane (2000) find that universities with policies with higher minimum inventor share of royalties produce fewer startups. This result is consistent with the claim that opportunity costs associated with entrepreneurship influence academics' decisions.

[15] We know of no general survey of distribution policies, but informal interviews with licensing personnel suggest that generally the licensing offices receive proceeds to recover expenses, or perhaps some constant share such as 15 percent and the remainder is distributed between the inventor, the inventor's department, and the inventor's school. Other recipients include, at times, a general university fund and the inventor's lab.

[16] One may speculate that it may be easier for a university based transfer office to solve information asymmetries pertaining to the quality of the invention through the establishment of reputation, an important problem in technology markets. In addition, there may be complementarities between the office and other university bodies that are best realized when the office is internal. For example, Argyres and Liebeskind (1998) argue that by internalizing the functions of technology transfer, universities are able to minimize the impact of conflicts of interest that arise between commercialization activities and open-science activities. At the same time, it is important to point out that TLOs may behave suboptimally. Siegel *et al.* [2002] report that they came across some TLOs that had an excessively legalistic or antagonistic approach, thereby making commercialization more difficult.

than a change in the character of academic's research (Thursby and Kemp, 2001; Mowery *et al.*, 2001; Henderson *et al.*, 2000; Thursby and Thursby, 2000). This suggests that an academic's choice to disclose her inventions are a response to incentives of the TLO system.

After a disclosure, TLOs evaluate the technology. If a favorable assessment is made, they attempt to identify potential licensees. A choice of technology transfer instrument (e.g., exclusive, non-exclusive license or option, materials transfer agreement, etc.) and choice of compensation mechanism associated with this agreement (royalties, equity, barter) are the outcome of negotiations with the licensee. Although TLO personnel may participate in negotiations that lead to complementary consulting or sponsored research arrangements, these are never part of the licensing agreements themselves as the university does not have the power to enforce such arrangements. TLOs provide valuable services. They encourage faculty to identify valuable intellectual property. They evaluate the commercial potential of inventions, they provide resources and expertise to protect the intellectual property, they assist in finding potential licensees, and finally, they are instrumental in negotiating with licensees and the formulation of license contracts.

In these efforts, TLOs commonly license technologies to established firms. This might be a distinct advantage as a) established firms may be more likely to succeed in commercialization as the added risk of developing capabilities in a new firm is avoided and b) small firms may find it difficult to amass resources necessary for some technology commercialization. The point is not to downplay the role of academic entrepreneurship. On the contrary, we have argued that incentives in equity arrangements are likely to be beneficial when significant academic effort is needed for success of a venture. Academic entrepreneurship is often the most effective means to facilitate technology transfer. It is important to understand, however, that it is not necessarily the best in all circumstances.

4. The Swedish System

The Swedish system of technology transfer has been much more directed. Bureaucratic attempts to directly establish university policy have been the mainstay of Swedish efforts to facilitate the transfer of potentially valuable intellectual property. As we shall see, these policies have largely ignored the importance of setting up incentives for universities and academics to pursue the commercialization of ideas originating in academe.

On the surface, incentives for faculty appear very strong: A 1949 law guaranteeing academic freedom also placed property rights emanating from their research entirely in the hands of faculty members (*lärarundantaget*). However, the outcome has been more complex. A consequence of full faculty ownership of property rights has been that the universities themselves have had little incentive to become involved in technology transfer to the commercial sector. In fact, as emphasized by Etzkowitz, Asplund and Nordman (2000) it has often been in the interest of universities to *discourage* contacts between faculty members and industry, since rigid civil servant pay schedules and other constraints have made it very difficult for them to retain highly valued personnel who have established personal ties with industry. Considering the extensive services provided by American TLOs, the lack of university support in itself may discourage the pursuit of commercialization opportunities.

This procedure is confounded by increased opportunity costs of pursuing new ventures. Procedures for academic leave have not been adjusted to make it easier for professors to take temporary leave to organize firms in the manner that has become widespread in the US (see also Stankiewicz, 1986, p. 90). Under these circumstances, Swedish academics are more likely to confine their external involvement to consulting activities, since to proceed further may force them to take a binary decision to leave the university, and few are prepared to do that (Etzkowitz *et al*., 2000).

In a system that discourages faculty involvement with industry beyond consulting and where the property rights rest with the researcher, there is a lower likelihood that the commercial benefits of academic research will be reaped. This is precisely because when pursuing entrepreneurial ventures, the downside risk of failure of the venture is increased as the researcher's faculty position is not ensured. The upside potential of the venture is mired by additional uncertainty as faculty inventors are unlikely to have significant business experience necessary to evaluate the market potential of new innovations. This effect is further reinforced in Sweden where small firms tend to remain small, and this may discourage decisions to pursue startups (Henrekson and Rosenberg, 2001). This is a difficult situation. Vedin (1993) points out that if the owner of the property rights shows little interest in exploitation, very little is likely to happen. This is also found by Etzkowitz *et al*. (2000), who conclude that "since most professors have little interest in commercializing their rights, or naively presume that discovery should somehow automatically produce rewards, relatively little use was made of these rights."

However, not only does awarding property rights to an individual create disincentives for the university, when property rights rest solely with the individual researcher, there is no "profit sharing" with his/her department. This has probably given rise to anti-entrepreneurial peer pressure at Swedish universities. Informal interviews as well as an in-depth government report on the collaboration between university and industry (SOU 1996:70, pp. 158–59) point to the existence of such pressure (see also Kenney, 1986, p. 116). US TLOs have mitigated this problem by awarding proceeds to the inventor's department.

Several scholars studying the Swedish university/industry interface emphasize that, analogous to what Zucker, Darby and Brewer (1998), Audretsch and Stephan (1996) and Siegel, Waldman and Link (2002) have found for the US, personal contacts are essential (e.g., Uhlin *et al*., 1992 and Etzkowitz *et al*., 2000). It is clear, however, that these contacts have been mainly with large firms, and it has turned out that the large firms have preferred that these contacts remain informal in nature. However, since many technologies are successfully licensed to large firms, it is possible that university personnel are successfully transferring their ideas through consulting arrangements, but not earning royalties because of insufficient licensing infrastructure.

But an absence of licensing agreements, or even increased difficulty in arranging them, is a significant restriction for transfer of intellectual property. Academics are much less likely to face strong incentives to continue to devote time and resources to successful commercialization when consulting is the only tool.

The Swedish private sector is greatly dominated by large firms (Henrekson and Jakobsson, 2001). As shown by Braunerhjelm (1998) industrial R&D is also highly concentrated to a few very large firms; in 1994 four multinationals carried out more than 70 percent of total R&D among multinationals. These large firms source knowledge from the outside mainly from highly specialized (mostly consultancy) firms: 28 percent of all

R&D in private industry in 1993 (13,700 of a total of 48,700 man years) was carried out in these firms (SOU 1996:70, p. 32). Thus, directly and indirectly, large multinational corporations tend to dominate private R&D activities in Sweden. Moreover, the large multinationals seem to be internally focused in their R&D effort in that they carry out a large share of their R&D in Sweden, while an increasingly large share of their production takes place outside of Sweden (Braunerhjelm and Ekholm, 1998).[17]

These facts reflect what has been characterized as the Swedish large-firm model of high tech innovation (Granstrand and Alänge, 1995; Lindholm Dahlstrand, 1997a; Edquist and Lundvall, 1993).

One additional disadvantage of large firms is that they are generally unwilling, or unable, to offer high-powered incentives to inventors (Anand and Galetovic, 2000).[18] As a result, they lack one potentially powerful tool to entice university faculty to cooperate efficiently with them. This is, of course, yet another reflection of the Swedish large-firm model of high tech innovation (Granstand and Alänge, 1995; Lindholm Dahlstrand, 1997a).

Edquist, Eriksson and Sjögren (2000) compare the sourcing of knowledge among (mostly small) high-tech firms in Sweden. They confirm that cooperation with universities is of limited importance compared to cooperation with other firms. Braunerhjelm *et al.* (2000) and Carlsson (2002) report findings from detailed studies of the biomedical clusters in Ohio and Sweden. They find that Ohio firms have been more successful in establishing links with the science and research community. The biomedical cluster consists mainly of small firms, and these firms have greater difficulties to establish links with universities than large Swedish firms. Carlsson (2002, p. 366) concludes that "the supporting organizational infrastructure, particularly with respect to venture capital and intermediary

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[17] This is not to say that within the group of large firms, the technology acquisition strategies of large firms in Sweden differ from the strategies of their counterparts in other countries. Granstrand *et al*. (1992) do not find any statistically significant differences between the perceived importance of various technology strategies among a sample of multinational high-tech firms in the US, Japan and Sweden in the 1980s.

[18] Anand and Galetovic (2000) discuss why it is often difficult for large, multi-product firms to tie rewards to a project's success. They point out that large firms can manipulate their accounts and hence costs associated with a specific project are non-verifiable. Drawing from Alchian and Demsetz (1972), they point out that many aspects of a firm's activities are shared across projects, for example, lab facilities, purchasing operations and managerial time. In addition, products are often cross-sold or bundled. Hence, not only will larger firms have a disincentive to correctly attribute costs to a project if outside compensation is tied to these costs, it may also be genuinely difficult to do so. Of course, large firms could compensate inventors

(bridging) organizations, is more developed in Ohio than in Sweden. These organizations contribute to a more rapid diffusion and utilization of technologies.”

Henrekson and Rosenberg (2001) point out that the Swedish government has attempted to address the failures in technology transfer for the last quarter century. The policies used have included an extension of the universities’ mandate in 1975 to communicate to the surrounding society results emanating from university research, and how they can be applied. This objective was eventually interpreted to imply collaboration between universities and private industry. This was formalized in 1998 (SOU 1998:128, pp. 153–154) where universities “are exhorted to be open to influences from the outside world, disseminate information about their teaching and research activities outside academia, and to facilitate for the surrounding society to gain access to relevant information about research results. Each university is also obligated to draw up and implement its own path for collaboration with the surrounding society. This plan has to be submitted for approval to the Ministry of Education” (p. 11).

This collaboration has taken many forms: Commissioned research projects, industry consulting, doctoral studies hosted in industrial labs, salaries paid by industry, research institutes and other organizations run jointly by universities and industry, university employed contact secretaries who act as mediators between university and small and medium size businesses. It is notable that none directly took into account the academic’s role in commercialization.

The success of these policies is mixed. Currently, industry-funded research has reached 2/3 of US levels, approximately five percent of academic research funding. University personnel are allowed to consult one day a week and often do. In contrast, the contact secretary program is generally regarded as a failure (Olofsson and Stymne, 1995). This is not surprising, as not only do they operate in a restricted environment; Swedish universities may be hostile to their activities if they believe they may lose academic personnel.

with royalties tied to sales. However, there is little evidence that this occurs with any frequency in Sweden, if at all.

In addition, since 1994 seven broker institutions called Technology Bridging Foundations (*Teknikbrostiftelser*) have been established in major university regions. Their task has been to mediate commercialization of R&D from universities, SMEs and individual inventors by facilitating the patenting process, matching up VC funding etc. In addition, four foundations, such as the Foundation for Knowledge and Competence Development, have been established which, among other things, are intended to provide a bridge between the university and industry. Although it is too early to evaluate the performance of these institutions, they will have several hurdles to overcome. In mediating commercialization of intellectual property, the Technology Bridging Foundations seem designed to accept responsibilities that in the US lie in the hands of university TLOs. Since Swedish universities do not gain from this commercialization, it is fair to assume that resistance to such activities by administrators and other faculty will continue. In addition, TLOs are not simply intermediaries, rather they help identify and protect intellectual property as well. To succeed, the bridging institutions will need to provide similar services.

The central difference between Swedish attempts at facilitating commercialization and the American experience is that in Sweden mechanisms are *designed from above*, while in the US they are encouraged to *evolve from below* and the intervention of policy has been largely to find ways to create incentives for such commercialization.

The above analysis has focused on the mechanisms best suited to facilitate the exploitation of university ideas and it also explored the rigid Swedish system so as to demonstrate that these mechanisms are often unavailable. However, it would be disingenuous to suggest that the reasons discussed above are the sole suspects for a weak Swedish performance in technology transfer. Sweden's private equity markets, underdeveloped until recently, have made it difficult to direct resources to commercialization efforts, its heavy taxation of entrepreneurial income dampens incentives to become an entrepreneur and its restrictive labor laws arguably are more harmful to small employers. These issues are discussed at length in Henrekson and Rosenberg (2000, 2001). During the last decade, Sweden has enacted several policies that have lowered the taxation of entrepreneurial income, relaxed some labor law restrictions and liberalized capital markets. Perhaps because of these policies, Sweden enjoyed an IPO renaissance in its stock market in the latter half of the 1990s. Furthermore, Di Gregorio and Shane (2000) find that the geographic proximity of VC funds is not a contributor to university start-ups, suggesting that if private equity markets are working at all, then good ideas will get funded. That said, Sweden's private equity market, even today, operates in a more restrictive environment than the US (Henrekson and Rosenberg, 2000, 2001).

5. The Swedish and American Experiences

This section compares the Swedish and American experiences in the commercialization of technology. This comparison is confounded by the nature of the data. In contrast to the US, there is a lack of comprehensive data that tracks the transfer of intellectual property from universities to the private sector in Sweden. There are several studies in which the unit of observation in Swedish studies is the firm, or spin-off. That is, the Swedish data inform us of all technology transfer in which the mechanism of transfer is a new firm, regardless of the existence of legally protected intellectual property. However, in US studies that use data from technology licensing offices, the unit of observation is usually the *invention*. These data report all transfer of defendable intellectual property and the mechanism by which the property was commercialized, if at all. Because of these constraints, we are only able to establish that the entrepreneurial avenue in Sweden is functioning rather poorly.

The reason for this difference in data availability foreshadows some of the conclusions of this study. The US data have been collected in various efforts (see below) from university technology licensing offices (TLOs). TLOs maintain a centralized source of data pertaining to their intellectual property. TLOs do not maintain data pertaining to consulting activities, nor do they follow all “spin-off” firms in which the founders are university employees, rather, they will do this only if the firm is using a technology that can be licensed. For example, we do not observe spin-off consulting firms in the US. In Sweden, property rights for innovations lie entirely with the inventor. Since universities lack an incentive to facilitate the transfer, central records of each innovation are unavailable, hence we do not observe transfer of technologies directly to large firms. This is unfortunate, as the basic normative concern of economists is not whether ideas are being commercialized specifically in new firms, but rather whether university ideas are being commercialized and contributing to the improvement of human welfare. The US data provide a more complete picture in which to assess this question.

This point cannot be overemphasized. In the Swedish studies, the criterion for entering the study is whether or not the firm was founded by university-based faculty. However, in the US close to 90 percent of university ideas were commercialized by methods other than the establishment of new firms (AUTM Survey, 1998).

Although we cannot compare how the transfer via large firms is working, we can establish that the entrepreneurship avenue is not working particularly well in Sweden. A careful reading of the research into small technology companies in Sweden reveals that none of them have become a large, significant presence in the Swedish economy (Utterback and Reitberger, 1982; Rickne and Jacobsson, 1996, 1999) and that this seems especially pronounced in the subset of these firms which are university spin-offs (Olofsson and Wahlbin, 1993; Lindholm Dahlstrand, 1997a, 1997b).

Although there are no directly comparable data in the US, at least by two measures TLO startups perform strongly. The TLO startups since 1980 have enjoyed a 70 percent survival rate through 1997 (AUTM, 1998). In addition, in 1998, universities held positions in 203 publicly held and 523 privately held companies. Although we cannot deduce from this number the exact percentage of university start-ups that go public, it is at minimum 8 percent.[21] This suggests that this mechanism of technology transfer from universities to the private sector is limited in Sweden by the large-firm bias in Sweden's institutional structure (see also Henrekson and Rosenberg, 2000).

We wish to make clear that the lower levels of startup activity in Sweden do not imply that Sweden is not commercializing any of its academic inventions. Indeed examining startups alone misses the lion's share of the transfer activity. In the US from 1980 through 1997, there were also 11,784 invention disclosures, 4,808 patent filings and 3,224 awarded patents, 3,668 new licenses, with only some 12 percent to start-up companies.

[21] This is under the assumption that these positions are all in companies founded since 1980 and that universities never liquidate their positions. It was extremely rare for universities to take equity positions

These figures are included to emphasize that in examining startup activities alone, as in Sweden, one misses a majority share of potential transfer activity.

This point is significant. The fact that university spin-offs do not lead to dynamic large firms does not necessarily imply that all valuable technologies are not being commercialized. Close to 90 percent of U.S. technologies are transferred to existing firms. If large firms are the best way to commercialize many university technologies, this may be favorable to Sweden as there is a strong large-firm bias in Swedish institutions, such as the tax code (Henrekson and Rosenberg, 2001). Hence, the absence of the entrepreneurial avenue may not be important if university technologies similar to those transferred via small firms in the US are effectively commercialized through larger firms in Sweden. Although there are no data with which to evaluate this proposition, it does not seem particularly likely. To support this proposition, one would have to believe, from a positive standpoint, that an environment in which small and new firms are disadvantaged is as conducive to commercialization of novel technologies as one in which they are not.

We employ two lines of argument to discredit this criticism. First, continuing involvement of academics is generally required for successful commercialization of their invention. If, as argued in section 2, larger firms are less able to provide strong incentives to academics than smaller firms, then large firms may not be the best way to facilitate commercialization in all circumstances. This statement is supported by empirical evidence. The best environment for innovation, in terms of firm size, is subject to significant variance (Pavitt, 1984; Acs and Audretsch, 1988; see also Cohen 1995 for a survey of a literature on innovation and firm size). The entrepreneurial avenue appears especially important in the commercialization of biotechnology, an area where, historically, knowledge has been very tacit (Audretsch and Stephan, 1996; Zucker, Darby and Brewer, 1998). In addition, this field is economically significant as biotechnological innovations have constituted a large share of university patenting activity in the US (Henderson *et al.*, 1998). Indeed, in a complementary article to this one, Gittelman (2002) finds a general absence of commercialization of biotechnology discoveries[22] in France. She attributes this absence to academics' incentives, which are much more similar to their

before 1980 (Feldman *et al*., 2001, figure 1), and as reflected by the USD 40M in revenue from liquidating equity positions in 1998, it is also untrue that universities never liquidate their positions.

[22] As measured by protein-based compounds that have reached the clinical trials stage.

Swedish colleagues' than to their American counterparts'. In contrast, in the transfer of small molecule discoveries, low-powered incentives such as research grants, awards or fee-consulting, appear adequate (Cockburn and Henderson, 1998). These authors also find that greater innovative output, as measured by patenting, increases as a firm's scientists co-author more with university collaborators. The fact that close to 10 percent of Swedish biotechnology articles with university authors are co-authored annually with scientists working in private firms and that 2/3 of these articles are coauthored with two large Swedish pharmaceuticals (Sandström, 2000) is consistent with the proposition that transfer of small molecule discoveries has been occurring in Sweden.[23] Second, in an argument we do not explore here in any detail, firms may be more reluctant to commercialize technologies that cannibalize existing markets or are perceived to be outside their focus (Christensen, 1997). Hence, based on the above arguments, we find the proposition that large firms fill the void of small firms in Sweden difficult to defend.

The point of this section was to demonstrate not only that the influence of new firms on the Swedish economy has been meager in recent years and that this likely stifled a share of academic innovations, but also to make a more subtle point: any assessment of the expected return of a new venture is likely to be low. Anecdotes of small firms which grew to be large successful firms in recent memory are rare in Sweden, which will influence academics' decision-making processes.

Although we do not claim that the comparison of Swedish and the US experiences is conclusive, we believe that the Swedish system has, at least until very recently, shut down the entrepreneurial avenue of commercialization. This most likely hindered commercialization activity. In some fields, such as biotechnology, the problem may have been severe.

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[23] It is beyond the scope of this article to exhaustively explore the relative importance of the entrepreneurial mechanism in commercialization by type of innovation and industry. We feel that this is an important topic for future study as the evidence overwhelmingly supports the conclusion that in some economically important fields, such as biotechnology, entrepreneurship is unambiguously important while in other fields it is not.

[24] 1998 may not be a representative year. However, historical data from AUTM suggests that the annual rate of increase in royalty revenues from 1991 to 1998 is 10–20 percent (see AUTM, 1998, pp. 51–52). Figure is in 1998 dollars.

[25] The remainder came from fees not associated with sales, such as upfront licensing fees and options.

6. The Supply of Ideas

Of more direct interest to this study because of its direct relevance to R&D policy, it is useful to explore to what extent a slow rate of technology transfer might be due to a low supply of university ideas.

It is straightforward to establish that there is extensive support for academic research in Sweden. R&D conducted in the university sector, as a share of GDP, is consistently the highest in Sweden when compared to the US and other OECD countries.[26] An extremely large share of R&D conducted by persons holding a Ph. D. is carried out in the university sector in Sweden – in 1993 the total volume of R&D conducted by Ph. D.'s in Sweden amounted to 9,650 man years, and 52 percent (5,000 man years) of this volume was carried out at universities (SOU 1996:70, p. 32).[27,28] This large concentration of resources in universities has led to a comparably large contribution to academic knowledge. In terms of publications (in recognized professional journals) per billion U.S. dollars of GDP, Sweden was second only to Israel in 1995 in terms of publications relative to the size of the economy, while the U.S. ranked 20th at less than half the Swedish level (National Science Board, 2000).

As noted above, comparisons of relative performance may not be helpful when trying to determine if there if the supply of ideas is sufficient to create a meaningful number of commercial opportunities in relevant fields. The Swedish academic performance in biotechnology is arguably significant. Between 1986 and 1997 Sweden produced 28,418 academic papers in biotechnology which is roughly 8 percent of U.S. levels and 2 percent of the global share.[29,30] Certain institutes have remarkable levels of output. For instance,

[26] As used here the term universities also includes colleges.
[27] It is approximately 6 percentage points higher when measured as a share of labor input rather than as a share of expenditure – see OECD, *Basic Science and Technology Statistics on diskette, 1997.*
[28] According to the same source 76 percent of total R&D at universities was in technology, natural sciences, biomedicine and agricultural sciences.
[29] These figures were drawn by Sandström (2000) from the Science Citation Index. The publisher of the index, ISI, categorizes journals by field. The Swedish statistics reflect papers in journals of the following fields: Biochemistry and molecular biology, biophysics, biotechnology and applied microbiology, cell biology, medical chemistry, mathematical methods for biology and medicine, biomaterial science, micro-biology, neuroscience and virology. The index is not a comprehensive list of all publications, rather it focuses on journals that are most highly cited.
[30] We should be cautious in comparing these academic output measures of the US and Sweden. The categories of the U.S. statistics are not identical to those from the Swedish study. Both statistics are drawn from the Science Citation Index. However, if anything, these estimates understate the Swedish

the Karolinska Institute has been producing between 500 and 900 articles annually during this period and around 10 percent of these were with industrial collaborators. In addition, Swedish authors are publishing in more important journals (see Sandström, 2000, for further detail). But, the fact that Sweden is producing academically valuable output does not indicate that that output is commercially valuable. For example, despite this high record of publication, from 1986–1997 Swedish inventors are responsible for less than 1 percent of new U.S. patents in biotechnology, and 30 percent of those were due to two large pharmaceuticals (Sandström *et al.* 2000). This commercialization record appears to be changing. Sandström *et al.* also report that there are currently around 150 small and medium-size biotechnology companies in Sweden, which is just over 1/3 the number of such companies in California.[31] A large share of these companies originated in the late 1990s, perhaps in response to a series of reforms that diminished the small-firm bias in the Swedish tax code and an increase in the availability of venture capital funds (Henrekson and Rosenberg 2001). Sandström *et al.* report qualitative data in which players in the biotechnology industry specifically identify incentive problems of academics as a barrier to further cooperation between university researchers and the biotechnology industry. A university-industry interface that correctly takes into account academics' and universities' incentives will further increase the production and exploitation of commercially valuable ideas.

Attempting to establish whether or not commercial influences are strong enough to affect the direction of academic work (as opposed, for example, to influencing the sharing of information among colleagues) is a difficult endeavor. There is a small literature attempting to shed light on this question, and the results are mixed. On one hand, Mansfield (1995) finds that university researchers who receive research grants from industry report that "problems they worked on in their academic research frequently or predominantly developed out of their industrial consulting – and in many cases, the cited academic researchers' government-funded work stemmed from ideas and problems they encountered in industrial consulting". Over 1/2 reported that the direction of their work and choice of topics were influenced by potential sponsors or users of their research output. This evidence suggests these researchers are producing knowledge that has higher

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accomplishment as the U.S. statistics reflect publications in a broader category of biomedical research (National Science Board 2000, appendix table 6-48).

[31] American data is from Ernst & Young, *Focus on Fundamentals: The Biotechnology Report*, 2000.

commercial value than if they had lacked industry connections. On the other hand, Brooks and Randazzese's (1998) brief survey of evidence suggests that industry influences may affect the academic value of output. However, if there is an effect, it is quite weak. We note that this implies that any affect on academic output does not correlate very well with its traditional measures, publications and citations. That is, by virtue of their connections with industry, there is little evidence to support the claim that university researchers are producing output of less *academic* value. Other evidence is mixed. Goldfarb (2001) finds that researchers supported from a very applied government program do not produce output that is less cited than those who do not. However, he also finds that those supported researchers produced less output in general compared to those who were not supported.

Di Gregorio and Shane (2000) find that universities that receive research funds from industry are more likely to produce more startups. However, the effect, if it exists at all, is very weak. Henderson, Jaffe and Trajtenberg (1998) find that the mean importance of university patents declined between 1965 and 1988, a time when commercial influence on academic research has been increasing. However, Thursby and Thursby (2000) suggest that universities have also exhibited an increased propensity to patent marginal inventions, which would suggest that Henderson *et al*. (1998) are finding a shift in university patenting policies rather than a shift in the overall portfolio.

The evidence of how the perception of entrepreneurial opportunity affects the choice of research decisions is limited to anecdotes. Kenney (1986) finds several examples of academic research being directed towards commercial goals when the principal investigator has a financial interest in a certain direction of research. However, these examples all pertain to research undertaken *after* a venture had begun and when the primary investigator had an equity stake in the sponsoring company. One might hypothesize that once researchers observe colleagues engaged in commercial activities, they might intensify their search for commercially valuable ideas themselves. Di Gregorio and Shane (2000) report a skewed distribution of start-up activities in a few universities, especially those located in areas with much entrepreneurial activity. This fact would support such a hypothesis. However, at present, it is not possible to determine whether this effect, if it exists, is small or large. This ignorance makes it difficult to assess if the supply of ideas of potential commercial value in Sweden is retarded by simple comparison of incentive structures. Nevertheless, it is *unlikely* that Swedish university personnel have strong incentives to produce commercially valuable knowledge.

7. The Larger Institutional Context

Before we make policy recommendations, it is prudent to recognize that the policies aimed at facilitating technology transfer exist in the larger context of their respective university systems. In contrast to the Swedish system, American universities are highly decentralized and intensely competitive. The decentralization implies that American universities retain a high degree of autonomy, thus pursuing opportunities for solving their own problems and for building upon their own unique strengths and aspirations. Competition takes place along several dimensions: (1) competition for students among universities (including competition between private and state institutions), and at the graduate level among professors for the best students; (2) competition among universities for the best professors in a cultural and economic context where the mobility of professors is very high; (3) competition among professors for research support, which provides released time from teaching and access to research assistants, equipment and other requisite materials. A university that can offer high quality teaching in fields for which there is a strong demand in labor markets can also charge higher tuition fees, which also leads to higher revenues.

As a result of the decentralization and the competition that takes place at so many levels, the US university system has become more responsive to the economic needs of society.[32] In order to justify high tuition fees, students expect a high degree of relevance of the offered curricula. Likewise, professors who are dependent upon research grants in order to be able to pursue a successful research career, are more likely to adjust their research interests to fields that have a high current or expected future economic value (Rosenberg, 2000).

Because of the decentralization and the competition among universities for professors who are visibly productive, the American system tends to result in greater salary dispersion, where salary differences are likely to reflect the economic relevance of the professor's field of specialization as well as his/her higher achievements as a researcher and teacher. Generally, professors active in research prefer to teach at the graduate level, where course content is closer to research at the frontier of the discipline and where students may come to play crucial roles in advancing those frontiers. Rosenberg (2000) presents evidence showing how rapidly entirely new fields as well as major breakthroughs in established fields have been introduced into the curricula at leading US universities over the years. In the US, therefore, universities can, to a considerable degree, be regarded as endogenous institutions that tend to be characterized by an impressive capability, as well as a strong incentive, to adjust to changes in the outside environment. Competition for faculty is particularly relevant. Kenney (1986) finds that universities often adopt liberal policies in order to attract top faculty.

In these respects the Swedish and, for that matter, the corresponding systems in most other European countries differ substantially from the American university system. Traditionally, European professors have, by and large, been civil servants working within the public sector, which implies that a high degree of national uniformity has been imposed on pay schedules, rules for promotion and recruitment and other working conditions. Essentially, this is still the case also in Sweden, although it should be noted that greater flexibility in terms of pay schedules has been introduced during the 1990s. Nevertheless, the Swedish system differs from the American system in a number of important respects that are likely to impact unfavorably on the inclination to introduce changes in curricula and research orientation in order to accommodate the changing needs of the economy.

First, there is a greater separation of teaching and research. The bulk of undergraduate teaching at Swedish universities is carried out by lecturers who do not do research. This is likely to slow down the pace at which important new research findings are integrated into the curricula. If there are strong complementarities between teaching and research, teaching is likely to benefit when research-oriented faculty delivers it. Also, research is probably better when it is carried out in association with advanced students in an intellectual environment that encourages and rewards informed criticism.

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[32] Argyres and Liebeskind (1998) examine the adaptation of US universities from a different perspective. However, their factual description is fundamentally similar.

Second, in contrast to the US, the Swedish university system is highly centralized. All universities are government-owned,[33] and entry of private universities is disallowed. The central government is the body that grants charters to universities, and in practice it also decides on the rules of admission and the size of a university (through budgetary allocations), as well as the size of specific *fields* of study. Due to this strong influence from the central government there is also much less leeway for individual institutions to allow remuneration to track an individual professor's research and teaching performances more closely and to vary the level of remuneration according to the economic value of the professor's field of specialization. Moreover, greater centralization also makes it more difficult for individual universities to adjust the allocation of its research budget across fields in response to changing demand outside the university.

One way of illustrating this lesser ability to adjust to changing needs is given by the comparison by Jacobsson, Sjöberg and Wahlström (2001) of the number of degrees awarded at the B. Sc. and M. Sc. levels in electrical/electronic engineering and computer science in Sweden and the US, relative to active-age population in the 1977–95 period. For a very long time there was an excess demand for engineers within this specialization in Sweden. Still, the university system was slow to respond to this increased demand through an expansion in teaching. In the US, on the other hand, the number of degrees awarded tripled from 1977 to 1986, while the Swedish expansion did not take off until the number of degrees awarded had already peaked and begun to decrease in the US "market driven" system.[34] When the number of B. Sc. degrees began to decrease, the US experienced a dramatic upgrading, with a large increase in the number of M. Sc. and Ph. D. degrees awarded (National Science Board, 2000).

The point, then, is not that the Swedish system of higher education simply failed to respond to a huge increase in the demand for trained personnel in the burgeoning fields of microelectronics and computer science. Rather, the point is that the response did occur, but it occurred, from a purely economic point of view, much too slowly. In considering

[33] With the exception of the Stockholm School of Economics, founded in 1909 and admitting 300 undergraduates per year. However, the School's contract with the central government bans tuition fees.
[34] Much of this increase may have reflected an export, in that many of the recipients of this training were foreign students. For example, in 1999 1/3 of Ph.D. recipients in the US were non-US citizens. This suggests that not only has the US system been responsive to US needs, it has been responsive to a broader opportunity and pursued excellence in recruiting the very best students worldwide.

universities in their specific role as suppliers of trained personnel in appropriate fields of study, timing is a crucial consideration. In competitive world markets, large economic rents are commonly available to those firms (and those countries) that can respond most quickly to economic opportunities opened up by new technologies or new disciplines. But late arrivals are most likely to find that the large financial rewards have already been captured as competitive forces have driven prices down to much lower levels.

Third, in Sweden and other European countries, university degree requirements are typically formulated as a fixed program rather than a flexible accumulation of requirements and credits as in the US. In such a system it is therefore more difficult to make changes than in the American case. Etzkowitz *et al.* (2000) present evidence from their interviews that it is very difficult to change courses quickly and to introduce new fields in the old Swedish universities.

The above discussion demonstrates that Swedish universities have a tendency to be insular. It is likely that this ivory-tower effect transcends the educational objective to the research objective as well.

8. Conclusions

Sweden is a country putting a great deal of resources into R&D; R&D spending relative to GDP has been the highest in the world for more than a decade. On per capita levels, the country also hosts several world-leading firms with a high R&D intensity, it holds a world class position in terms of publication rates in leading academic journals, and its government invests massively, given Sweden's size, in the building of organizations to bridge the gap between university research and industry. In some key fields, Sweden is producing large absolute amounts of scientific output as well. At the same time, incentives for academics to establish intellectual property rights and pursue commercialization of their technologies are weak. Although the general performance of technology transfer in Sweden is unknown, it is clear that the performance of its academic-based startups is weak. The U.S. picture, on the other hand, is quite different.

This study attributes this difference to the distinct policies pursued by Sweden and the United States. The Swedish government has pursued a portfolio of policies aimed at directing funds at entrepreneurial activities in general, and specifically at the commercialization of academic research output. These policies have been largely ineffective due to a lack of incentives for academic researchers to become involved in the commercialization of their ideas. This, in turn, has likely dampened the incentives for academics to pursue commercially relevant areas of research and/or exploit commercially relevant applications of generic knowledge. The environment created by the Swedes sits in stark contrast to that in the U.S. In the U.S., the emergence of the flexibility needed to exploit commercially valuable research output is due to the relative lack of regulation as well as the intensive competition for research funds by researchers and research talent by universities. In particular, academics in the U.S. are relatively free to respond to market incentives for the commercialization of their ideas. By contrast, in Sweden, researchers risk being *penalized* for attempting to commercialize their ideas. These results are likely to be widespread throughout Europe. For example, Gittelman (2002) suggests that poor performance in the commercialization of university biotechnology results in France is due to lack of incentives for French scientists to get involved in the commercialization process.

We have also pointed out that universities have strong influence on academics extra-curricular activities. When policies are top-down, the desire of universities to implement them may vary, especially, as we have described above, since these universities face conflicting incentives. This has, in turn, affected academics' incentives to pursue commercial opportunities. Not only has it dampened financial incentives, especially because of larger downside risk, but it has also created *de facto* professional penalties for engaging in commercializing activities. Therefore, a policy aimed at encouraging the commercialization of intellectual property should recognize that universities have the ability to restrict the pursuit by their faculty of commercialization opportunities, and policies directing them to encourage such activities are likely to fail if they are unlikely to gain from such pursuits.

Interestingly, putting property rights in the hands of the inventor does not automatically create the best incentives for commercialization. To facilitate involvement in commercialization activities, not only must an academic inventor face strong incentives in the market for technology, but she must also not face strong disincentives in her university environment. The system works better when incentives are aligned.

Because of lack of data, we were only able to determine that Sweden has performed poorly in academic entrepreneurship. We have discussed conditions where this shortcoming is significant and with the likely under-harvesting of research results in the field of biotechnology. The exploration of the impact of the Swedish (indeed European) incentive structure on other fields remains an open question.

Hence, even if the goal of a policy is to facilitate the commercialization of academic ideas, one cannot draw the conclusion that, based on US experience, property rights should be handed over to the university. First, awarding property rights to universities works in the US because universities are largely autonomous, competitive institutions. In Sweden, however, universities are state- owned bureaucracies. Further study is needed to determine if, after adopting this policy, university bureaucrats would face strong enough incentives to develop offices similar to US Technology Licensing Offices. Second, even if such a policy worked, it is unclear if the benefits would be widespread enough to offset the costs in terms of the sacrifice of academic norms.

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