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Well-springs of Modern Economic Growth: Higher Education, Innovation and Local Economic Development

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Introduction

Modern economic growth is a complex phenomenon that is increasingly dependent on innovation -- the ability to create economic value through the creative application of knowledge. Knowledge is arguably the most important commodity of the modern economy and universities are the primary creators of this currency. While universities have long served as a source of knowledge creation and dissemination for industrial activity, relationships with firms and engagement with for-profit activities are becoming more direct and focused. Indeed, one of the responsibilities of institutions of higher education is now to create effective mechanisms to transfer knowledge, whether the purposed is social or economic development, enhanced economic competitiveness or simply increasing the stock of knowledge and increased understanding about the world. Of course, knowledge is an ethereal concept that is perhaps best considered as embodied in human capital- individuals who have received the benefit of education and who are able to appreciate, integrate and augment knowledge and innovate. Skilled human capital requires investments in higher education –institutions dedicated to advanced learning, sophisticated research and public service important to the functioning of the modern economy.

Increasingly we also recognize that geographic units smaller than nations, commonly identified as regions or places are the locus of creative activity. Alfred Marshall wrote about the importance of the local organization of economic activity for enhanced productivity and efficiency over 100 years ago. This is a well-know rather than arcane contribution due to the emergence of places like Silicon Valley and Route 128 and a series of other prominent local industrial complexes. Research universities and other institutions of higher education figure prominently in accounts of the development and genesis of these industrial clusters

The question then becomes how to best create and enable human capital with the ultimate goal of reaping rewards in terms of wealth creation and increased standards of living. While attention has increased considered the role of research universities, it is more appropriate to consider higher education, the more diverse sector that includes the complementary and reinforcing institutions such as liberal arts colleges, institutes of technology, professional schools, community colleges and continuing education programs. Taken together, these academic institutions provide the basis for the range of skills required for advanced economies and form the fabric of competitive regions. How to best organize higher education in order to create and transfer knowledge to sustain innovation and economic growth is an important question for both advanced and developing economies.

The intention of this paper is to provide a framework for considering the evolving role of institutions of higher education in the economy and in generating economic growth and development. The goal is to provide a solid overview of the recent literature and thought pertaining to universities and knowledge transfer. This is a significant task. We begin by clarifying some terms.

Clarifying Terms

When an issue is significant the popular discussion may easily become muddled, terms may be used interchangeably and without precision and as a result the debate becomes superficial. To avoid this, a series of definitions that discriminate between the components of innovation will be provided in order to advance the discussion and enrich the choice of policy options. In daily conversation, terms like *invention* and *innovation* as well as *science* and *technology*, among others, are often used interchangeably. However, for academics and policymakers there are important distinctions between these terms and these distinctions give each term a unique meaning and enrich discussion. Invention is about discovery and the creation of something novel that did not previously exist. Innovation, on the other hand, carries invention further with the commercial realization of the value of the invention or the receipt of an economic return. This is a subtle but important distinction. Thus, patents, the legal protection of an idea reveals an invention while, for example, the marketing and consumer acceptance of a new drug is evidence of an innovation.

Science, in a broad sense, is the unfettered search for knowledge for the sake of understanding. That search is based on observed facts that may be replicated through experimentation or theory. Thus, science begins with conventional preliminary conditions and searches for some unknown results to address fundamental questions related to hypotheses about the world. The process of investigation is known broadly as research, and research may be *basic* with the intention of advancing science or *applied* with the orientation towards some practical end. These are two ends of a continuum of problem-solving, as basic research suggests avenues of inquiry that are advanced by applied research. Likewise, research is enriched, made more complex and significant, as applied work creates the need for more theoretical work and suggests new avenues for further basic research. In addition, and most critically, while science is classified by disciplines that define traditions of inquiry, and scientists are trained within these specific traditions, applied problem-solving frequently creates the need for multidisciplinary teams or even creates new disciplines to colonize the frontiers of knowledge. Examples would be the rapidly evolving fields of biochemistry and biomedical engineering or the emerging fields of nanotechnology, genomics or proteomics.

In contrast, industrial *Research and Development* (R&D) is the systematic augmentation or deepening of knowledge by applying it to some practical problem or new context with the idea of generating a commercial return. While science is typically conducted by universities and institutes of higher learning, R&D is typically conducted by private firms. An important distinction is that private firms have a responsibility to earn returns for their shareholders. In general, the more basic the science involved in a research project, the more difficult it is to appropriate the resulting returns. This is due to particular characteristics of the knowledge that research creates. A variety of government incentives and public-private partnership programs have evolved over time from government's desire to steer private investment towards more basic types of scientific activity, and to stimulate the development of new technologies that private firms would not consider attractive investments in the absence of some incentives. These incentives include direct grants, R&D subsidies or other programs that encourage firms to conduct projects with universities or government laboratories.

A similar distinction may be made with regards to education and training. While training is task oriented, education has a broader goal of increasing knowledge.

Knowledge has characteristics such as being nonrival and nonexcludable that classify it as a public good. *Nonrival*, in the economists' terminology, indicates that one person's use of knowledge does not impede another's use of it. Consider the example of a mathematical formula. Knowledge is created when the formula is first derived and formal proofs are demonstrated. The result is most likely a scholarly publication which would codify the knowledge, rendering it easy to diffuse and put into practice. Once the formula is known, the fact that one scientist uses it does not diminish its usefulness or utility to other scientists. In fact, the value of the formula may actually increase as a result of its more diffuse use and acceptance. Thus, knowledge, once created, is nonrival in that many economic actors may enjoy it simultaneously. *Nonexcludability* refers to the fact that once knowledge is discovered it is difficult to contain or to prevent others from using that knowledge. Once an idea is known it frequently seems obvious to others and can be simply replicated at what is known as zero marginal cost. As a result of these two conditions, the social value of knowledge is greater than the value that the creator may be able to capture, a classic case of an externality. Private firms are likely to under-invest in knowledge production since the returns to the firm are smaller than the returns to society. This is the traditional justification for government funding for research.

Intellectual Property (IP) can take many forms including products and processes that can be protected through patents or trade secrets, or authored works protected through copyright. Most governments consider certain kinds of creative endeavors as “intellectual property” and allow inventors legal recognition for these endeavors. For example, some forms of IP include software, databases, plant varieties and other biological materials, as well as "tangible research property". The latter includes items such as circuit chips, organisms, drug targets, formulations and engineering prototypes. It is however, up to the creator to decide whether an invention, discovery or new idea is to be treated as IP. For example, a researcher who immediately publishes a discovery has made the decision that it is not to be treated as IP and that it should be freely available to the public for use.

Commercialization is the process that turns an invention into an innovation and involves defining a concept around who is willing to pay for the new idea, what attributes they value and how much they are willing to pay for the added value. The ability to legally protect an invention therefore forms the basis for commercialization activities, as it precludes others from copying the invention and entering in the market and competing for a share of the economic profit. More importantly, if firms did not have the ability to protect their discoveries, they would have no incentive to invest in many important research and development (R&D) activities such as clinical trials, thus interfering with the creation and diffusion of knowledge. As such, IP creation is a fundamental ingredient of the commercialization process and an important vehicle for knowledge transfer between legal entities and the public.

While patenting measures invention, commercialization requires the additional steps of translating inventions into consumer needs and product markets. At its earliest stages, before applications are easily described or generally appreciated, realizing the potential of an invention requires a sophisticated understanding of consumer needs, existing markets for product innovation and factor inputs. Commercialization, even when ideas are abundant, may not be completed because outcomes are highly uncertain, risk aversion may cause projects to be delayed or abandoned or the relevant organizations may not be able to collaborate.

Technology is information that is put into use to accomplish some task. This information may take many forms including both hardware (physical, material objects) and software (digital or procedures) or combinations thereof. As such, technology has a fairly broad definition and includes anything that helps increase the efficiency and quality of our daily lives. For example, electronic and computer technology help use share information and knowledge quickly and efficiently. As well, vitamins, new biochemical formulations and drugs alter our health and improve our lifestyle making up another important class of technology. Using this definition, technology may often be considered a form of intellectual property. In general, technologies are often broadly classified based on their area of application and therefore terminology such as information technology (IT), biotechnology and nanotechnology have become common place.

Technology transfer is the application of information into use where transfer is essentially the communication of information or technology. Technology transfer is therefore a distinct and important subset of knowledge transfer. In the literature, technology transfer is often considered as a formal activity within or across organizations. For example, a discovery derived from research in a scientist's lab may be licensed to a firm that will commercialize the technological innovation into a product or service to be sold in the marketplace. Or the receptors may be nonprofit organizations that adopt a new technology such as a new treatment idea to better serve their clients (see, e.g., Cunningham et al. 2000). Direct technology transfer is often handled by specific offices or departments within an organization such as technology transfer offices (TTOs) or business development offices (BDO's).

Knowledge Transfer Mechanisms

Most modern institutions of higher education have well-developed policies, practices and infrastructure in place to support the transfer of knowledge. As highlighted in Figure 1, knowledge is transferred from the university through formal and informal mechanisms. There is typically greater emphasis on formal channels of knowledge transfer and market transactions as these are easier to measure and evaluation. Of course, the informal and less direct role, while more evasive, may be more important. The public space function of institutes of higher learning provides meeting places for serendipitous interaction and chance encounters and may result in the formation of diverse networks that facilitate novel ideas and creativity. There are attempts to formalize the informal mechanisms of knowledge transfer as, for example, the benefits of co-location become interpreted as the justification for science parks and incubator facilities.

The historical conceptualization of innovation, the linear model, places institutions of higher education at the earliest stage of knowledge creation and focused on university research as the generator of ideas. Yet, in practice, university research involves a rich mix of scientific discovery, clinical trials, beta testing, and prototype development and industry linkages to university-based research are demonstrated to be complementary to firms' R&D strategies (Bercovitz and Feldman 2005). Cohen, Nelson, and Walsh (2002) find that more than one-third of industrial R&D managers use university research as an input. In a survey of R&D managers, Mansfield (1998) found that, in the absence of academic research, approximately 14% of new product introductions in seven U.S. industries would not have been developed without substantial time delay. Beise and Stahl (1999) arrive at similar results for industrial innovations in Germany. The importance of technology transfer varies considerably among industry sectors; however, generally university-industry partnerships are more important in sectors where science plays a major role as is the case in the biotechnology and information technology fields. The Yale and Carnegie Mellon Surveys of R&D labs have tended to emphasize industry differences, noting that pharmaceutical firms spend the greatest percentage of sales on R&D and tend to use university research disproportionately (Klevorick et al. 1995; Cohen, Nelson and Walsh 2002).

From the firm's perspective, it is generally accepted that collaboration is primarily a valuable complement to, and extension of, the firm's in-house research, and not a way to replace it. Access to the outside knowledge, expertise and awareness of leading-edge research and access to independent verification or inquiry provide incentives for firms to seek collaboration with a university. Research from higher education entities enables firms to see that the solutions are chosen from among the array of options that are outside of the firm's day to day considerations. Collaborative R&D projects involving universities and other higher education entities are frequently supported by matching funding from various levels of government, thus reducing the cost of doing research.

From the institutional perspective, interest in collaboration is stimulated by three factors. Two relate to the financial pressures resulting from growing public demand to see economic value from the public investment in education and research, and from the fact that a larger share of public funding is contingent on finding private sector co-funders in the form of matching grants. The third factor is the interest of researchers in seeing that the results of their work are relevant and being applied by industry.

Formal Technology Transfer

Technology transfer and the flow of knowledge from the university to the firm, is dependent on the characteristics of the firm, the university and more importantly the efficiency of the technology transfer office (hereafter TTO) in bridging this gap. As such there are many important actors involved in this process. Figure 2 provides an overview depicting how technologies flow from the university to industry. Based on this process the key stakeholders are: 1) university scientists, who make discoveries that may either be published in traditional knowledge dissemination or protected as intellectual property; 2) university technology managers and administrators, who serve as a liaison between academic scientists and industry and manage the university's intellectual property; and 3) firms/entrepreneurs, who license and commercialize university-based technologies. A summary of these key stakeholders, their roles and motivations in the process are listed in Table 1 as described by Siegel et al. (2004).

Technology transfer begins with a discovery by a university scientist in a laboratory, who is typically working on a federal research grant (e.g., a research project funded by the NSERC or CIHR). The academic must then decided whether to file an invention disclosure with the TTO and, more importantly, whether they wish to work with the TTO in commercializing the invention. This process will be largely governed by the prevailing invention disclosure and IP policy of a given institution, and by the perception/awareness the researcher may have of the TTO. In the U.S., the Bayh-Dole act of 1980 (Bremer 1993) requires that all discovery originating from federal research grants be disclosed through the university TTO. Of course, the academic may elect to forego commercialization and publicly disclose the invention through a research publication, making it freely accessible to the public. When the discovery is disclosed through the TTO, however, the TTO managers must evaluate the technology and decide whether or not to patent the innovation and protect the intellectual property. The evaluation step is very important and requires experience and sound judgment because the process requires time and many universities have limited budgets for filing patents, which is quite expensive if global patent protection is sought. Universities may choose to apply for domestic patent protection, which safeguards the technology at a much lower cost, or use provisional patents as a way to stop the clock. Provisional patents will cost less and may be used when more time is required to evaluate the technology and its marketability, or to buy time to collect more data to file a stronger patent. In general however, the review process will consider IP reviews, technical analysis, market assessments and commercialization strategies. If there is known interest in a technology by an industry partner, the decision to file a patent is often expedited. Once the IP has been protected, the technology will be marketed. The business development portion of this activity will be led by the TTO; however, faculty members will often provide additional technical input and help identify industry partners. Once the TTO has secured interest by an industry partner, it will enter into negotiations to license the technology focused on obtaining a royalty stream against future revenue streams from a commercialized product or an equity stake in a new venture.

The simple description of technology transfer implies that it is primarily a one way or linear translation of research results into various commercial applications. In practice, however, the technology-transfer process is more adequately viewed as a relational process in which questions, answers, clarifications, and other information flow in both directions. In such cases, research has suggested that the efficiency of the transfer of technologies is related to the firm's connectedness with the university research and or inventors and this is facilitated by frequent interaction. Appreciation of new discoveries ad the subsequent commercialization of new technology is highly uncertain and requires a shared vision of what the discover potential might be, how to best move the technology forward and even requires coming up with a lexicon and terminology to even talk about the discovery and its related components. Using this approach, the receptor organization transforms the research-based technology into a product or service that can be sold in the marketplace by constructing a common, shared meaning of the technology with the inventor/university through frequent interaction, questioning and skepticism and creative playfulness – what the literature describes as the transmission of tacit knowledge.

Although the transfer of technology from academic practitioners to industry is an easily described process, reality can be quite complex. As described by Siegel et al. (2004) in Table 1, it requires consideration of the actions, motives, and organizational cultures of scientists, university administrators, and firm/entrepreneurs. For example, Merton (1957) suggests that a primary motive of university scientists is recognition within the scientific community, which emanates from publications in top-tier journals, presentations at prestigious conferences, and federal research grants. They are also motivated by financial gain, both for personal reasons and to secure additional funding for graduate students and laboratory equipment. The fraction of a licensing royalty payment that is allocated to a faculty member is determined by the university's "royalty distribution formula". It typically ranges from 25 to 50% (although it can be as high as 75%). In these arrangements, the TTO works with the scientist and firm or entrepreneur to structure a deal, where the primary motive of the TTO is to safeguard the university's intellectual property, but at the same time, market that intellectual property to private firms who can move the technology forward. Secondary motives may include securing additional research funding for the university via royalties and licensing fees, sponsored research agreements, and an intrinsic desire to promote knowledge transfer. Firms and entrepreneurs seek to commercialize university-based technologies almost exclusively for financial gain and therefore seek to maximize their returns. As such, control becomes a major factor when a firm enters into a relationship with an academic or university and the firm will often require exclusive rights to new technologies and focus on the "time to market," since the benefits from innovation may depend on rapid development of a new product or new process. Differences in the motives, actions, and organizational cultures of the three key stakeholders highlight the complexity of this relationship and its importance to efficient knowledge transfer from the university TTO to a firm.

Given the importance of this function, it is easy to understand that the university TTO has become a primary focus of study for those looking to understand and increase the efficiency of knowledge transfer. For example, Bozeman (2000) has conducted an in- depth and fundamental review of the literature where he considered approximately 200 references on the subject. In this work he had concluded that there were five key drivers that will impact the efficiency of the process: 1) the process orientation of the TTO (i.e. process *vs* results driven); 2) the probability of market impact (the commercial success or resulting economic development derived from the transfer); 3) the possibility for political gain (does fulfilling the technology transfer process have a political impact?); 4) the opportunity costs (does the prevailing culture view this to be important or a waste of time), and 5) the scientific and technical human capital (skill and quality of the participants in the process.

Table 2 summarizes the conclusions from a selection of more recent articles focused on TTO effectiveness tend to confirm the view that the organizational structure and strategy of the TTO in addition to the skill sets and motivation of the managers are critical to the effectiveness of commercialization-based knowledge transfer. Specifically, the university TTO manager must play a boundary-spanning role to effectively bridge the boundaries of the university-firm interface and manage the process. For example, the TTO may scan the industrial landscape for ideas and information about potential markets for new technologies bringing the manager in direct contact with entrepreneurs and intrapreneurs in the business domain. These sorts of interactions provide a necessary feedback mechanism and more adequately transmit the needs and interests of both the university and firm to each other. The boundary spanning performed by the TTO manager could involve relationship or network building that helps to facilitate effective communication with both stakeholder groups, and that forges alliances between scientists and industry. In many universities, the TTO director may have limited discretion and responsibility for technology transfer. A vice-provost or vice-president for research will bear ultimate responsibility for these activities. In many cases however, the core focus of the research offices is on publications and increasing public funding including research contracts with firms. They may however have limited experience with commercialization, and as such fail to fully appreciate the challenges and importance of technology transfer as a source of revenue, impact and local economic development.

Organizational culture and ability of faculty to participate is also an issue. All of the outcomes of interest are predicated on individual faculty member disclosing their inventions. There are multiple reasons why faculty may choose not to participate. First, it is claimed that faculty may not disclose because they are unwilling to spend time on the applied R&D required to interest businesses in licensing the invention. This is perhaps countered by the trend towards patenting basic scientific results from projects like the human genome which, though basic, may have immediate commercial potential. Second, faculty may not disclose because they are unwilling to risk publication delays which may be required to allow prospective licensees to initiate the patenting process. This is more a perceptual problem than reality. There are strategies to accommodate both academic and commercial interests and experienced peers can help navigate the process. The final reason faculty members may not disclose is because they believe that commercial activity is not an appropriate activity for an academic. This view represents an older norm of open academic science. However, to the extent faculty members actually do disclose inventions academic norms appear to be changing but we may question if this is changing the type of inquiry conducted and erode the basis for the type of academic discoveries that provide platform discoveries and promote economic growth.

Start-ups Companies

Start-up companies are a means to advance a new technology since established firms may be unwilling to invest in risky, unproven technology, especially if those new technologies may supplant their existing investments and expertise. The formal definition of a university start-up is a new firm created through the license of a university technology. The Association of University Technology Managers (AUTM) reports that 4,543 new companies have been formed around licenses of university technology 1980. The rate of increase is significant as 462 companies were formed in 2004.

Universities vary greatly in their approach to creating start-up companies which is typically more difficult that negotiating a license with an existing company. The number of start-ups is largely be determined by the availability of external resources and the experience of the TTO managers involved. Some universities create many spin-offs, whereas others are more focused on licensing than on spin-offs: their approach is to file a patent, search for a partner and hope that license fees and royalties will help support the research. Spin-offs are more prevalent in information technologies and biotechnology (except pharmaceuticals), while licensing is more common in pharmaceuticals and agriculture. The existence or absence of potential local resources, role models and advocates plays a role a significant role.

In general, the formation of new firms has become an attractive alternative to transfer technology to the commercial realm for several reasons. First, since many academic discoveries are early stage additional work is required to demonstrate proof of concept and to demonstrate the viability of the business model. Second, based on the successful examples of the Massachusetts Institute of Technology and Stanford University, credited with playing an active role in the genesis of industrial clusters in Route 128 and Silicon Valley respectively, university spin-offs are seen as a means for local economies to capture the benefits of proximity to local research universities.

Spin-off firms are local phenomena – the stay close to the source of their competitive advantage. AUTM reports that, on average, about 75% of start-up companies were located in the same state as the institution from which the company licensed the technology. For university-based spin-offs the university serves as the source of advantage providing skilled labor, specialized facilities and expertise. As universities and state governments have provided incentives for faculty to start companies or engage in joint research projects with companies the attraction of proximity to universities has grown. On average, 60% of university licenses are granted to small firms. In 1999, the Association of University Technology Managers (AUTM) reports that university licensing led to the formation of 344 new companies, with 82% operating in the same state as the university that provided the license.

Over the past two decades much has been learned about the management of academic spin-offs. Lerner (2005) summarizes lessons that may be generalized from his research, case studies of specific programs and service on advisory panels. First, starting new ventures based on university technology is hard. Despite the confidence of many academic entrepreneurs and university administrators, the process of creating a sustainable new company is very challenging. Second, in the vast majority of cases, new firms will not generate enormous wealth for academic institutions. More modest returns are the norm. Third, directly financing firms through internal venture capital funds is unlikely to be a successful strategy for academic institutions. Fourth, old frameworks about conflicts-of-interest must be rethought in light of the special needs of start-ups.

Similarly, in a much earlier review by Levin and Stephan (1992) focused on the motivation of universities and scientists and concluded that there are notable issues associated with spin-offs. First, the creation of spin-off companies provides a means to demonstrate an immediate and quantifiable impact. Second, university technology is often very early stage and larger firms may not be interested. Third, life-cycle models of scientists suggest that scientists invest heavily in human capital early in their careers to build reputation and establish a position in a field of expertise. In the later stages of their career, scientists typically seek an economic return for their human capital. For scientists, starting a company serves the purpose of appropriating the value of their intellectual property as well as providing access to additional funding mechanisms to further the scientist's research agenda.

In the U.S., the potential financial rewards of starting a company coupled with tightening university budgets and competition for the relatively fixed pool of public funding create incentives for scientists to engage in entrepreneurial activity (Powell and Owen-Smith 1998). In this regard, the ability of individual scientists to appropriate the value of intellectual property will be affected by national policies and variation in intellectual property procedures is one factor that may influence the academic scientist's decision to start new companies. From this, we can say that individual scientists who received grants and awards for basic research have the intellectual capital required to start a company; however, they may not possess the entrepreneurial spirit or the business acumen to run a company. In many cases, the TTO will play a major role in working with the scientist to put together a business plan, arrange funding and help establish the company.

Technology Transfer Policy Initiatives

Although each country will have developed their own set of policies regarding university-firm commercialization initiatives, it is true to say that policies introduced in the U.S. have had significant influence and often serve as a benchmark for other countries. This is largely due to the unusual structure of U.S. higher education, which blends financial autonomy, public funding from state and local sources, with federal research support on a substantial scale. This provides strong incentives for university faculty and administrators to focus their efforts on research activities with local economic and social benefits. Rather than being exclusively concerned with fundamental scientific principles, much of U.S. university research throughout the late nineteenth and twentieth centuries focused on understanding and solving problems of agriculture, public health, and industry. As a result, U.S. universities have made important contributions to industrial innovation throughout the past century, primarily by combining advanced research and education. The strong links between education and research sustained a close relationship between the evolving scientific research agenda and problems of industry or agriculture, while at the same time providing a powerful and effective channel (in the form of trained students) for the transfer and application of much of this knowledge to industry and other economic sectors. Given this history and accumulated research the U.S. system and policies therefore provides an important and relevant reference for the development of policy for other countries.

Three of the major U.S. legislative acts that have paved the way for the current technology transfer policy currently in place in most U.S. academic institutions. Specifically, in the late 1970's the U.S. Congress was influenced by many years of negative trade balances, and decided to change U.S Science and Technology policies. Congress recognized the need to use the research and technological resources of U.S. research universities and federal R&D laboratories by increasing the flow of knowledge and personnel to industry. The need for increased and faster technology transfer from universities to industry emerged as major legislation in 1980 when Congress passed three laws: the Bayh-Dole Act, the Stevenson-Wydler Technology Innovation Act, and the Cooperative Research Act.

All three pieces of legislation were important in providing the necessary foundation for universities to develop the infrastructure required to build and support knowledge transfer (commercialization) activities with industry. Of these three pieces of legislation and subsequent amendments, the Bayh-Dole act has received the highest degree of attention and critical review both from academics and industry observers. The act has been in place for over 20 years now, and organizations such as AUTM have made public large amounts of data collected annually from university TTOs..

In the past three years, two of the most respected business magazines, *Fortune* (Leaf 2005) and *The Economist (Dec 12, 2002)*, have arrived at diametrically opposing views on the impact of the act. *Fortune* decries Bayh-Dole; *The Economist* embraces it. More specifically, *The Economist* has gone so far as to say that it is "*possibly one of the most inspired pieces of legislation in the U.S. in the last 50 years*". *Fortune*'s criticism is largely related to the unintended consequences of increased litigation that amount to very significant 'hidden costs' associated with this process. As pointed out by an AUTM editorial (Crowell and Greenwood 2005), however, the legal costs associated with enforcing this legislation are largely those associated with patent protection rather than pure litigation.

Further context on the impact and issues associated with this legislation may be found in the current academic literature. For example, Shane (2004) has studied data associated with the impact of the Bayh-Dole act on university patenting in the United States and its effect on university entrepreneurship. In his study he found that the effectiveness of licensing in a line of business is significantly correlated with university share of patents in the post-Bayh-Dole period, but not in the pre-Bayh-Dole period. This result is consistent with the argument that the Bayh-

Dole Act gave universities an incentive to take a more commercial approach to patenting than they had adopted in the past.

Because universities can appropriate the returns to technological invention only if inventions can be transferred through licensing, and licensing is not effective for all technologies (Levin et al. 1987), this policy led universities to shift their patenting at the margin towards technologies in which licensing is more effective. Understandably this will result in TTOs focusing their commercialization efforts in more lucrative areas or technologies resulting in selection towards commercialization.

Furthermore, the post-Bayh-Dole shift in the focus to university patenting has important implications for understanding the conflict between university departments over technology transfer that has developed in recent years. Traditionally, all academics adhered to a norm of open dissemination of ideas for the benefit of the public good. However, the demands of private industry have led norms in fields closely tied to industry to move away from this tradition in the post-Bayh-Dole era. Because academics' views about technology transfer and their academic norms are shaped by the potential commercial value of their research, the focus of universities on patenting in fields in which licensing is effective in the post-Bayh-Dole era, may explain the conflict over technology transfer between academic units that transfer technology routinely, and those that do not. This raises questions about the future of unfettered basic inquiry.

Finally, the results suggest that the effects of changes in public policy be considered at the industry level (Levin et al. 1987). Appropriate technology policy in one technical field may not be appropriate in another because blunt instruments may have industry-specific effects that are inconsistent with their overall goals (Klevorick et al. 1995). Since most university inventions are early stage and require additional development before private firms may invest in their commercialization (Jensen and Thursby 2001), patent protection becomes critical in safeguarding emerging technologies. As such, this implies that policies which give universities the property rights to their inventions will lead universities to focus their patenting efforts in lines of business in which patenting and licensing is more effective, which does not broadly apply to all fields.

Mowery and Sampat (2005) study the Bayh-Dole Act specifically as a model for other OECD governments to follow and conclude that, in light of existing government-supported academic infrastructure, the Bayh-Dole Act appears to have been neither necessary nor sufficient for much of the post-1980 growth in university patenting and licensing in the U.S. Moreover, given the very different institutional landscape in the national higher education systems of much of Western Europe and Japan, it seems likely that the "emulation" of Bayh-Dole that has been discussed or implemented in many of these economies is far from sufficient to trigger substantial growth in academic patenting and licensing or university–industry technology transfer. Indeed, there is some question as to the necessity of a ''patent-oriented'' policy to encourage stronger research collaboration and technology transfer and whether the potential risks associated with such policy changes have received enough attention.

Although the debate still rages and other governments are cautioned not to blindly adopt Bayh-Dole strategies, the fact remains that governments around the world recognize the importance of developing a national policy and will often look to the U.S. model. For example, Germany, Korea, and Taiwan are the most recent countries allowing academic institutions, as opposed to individual professors, the right to own inventions resulting from research in their labs. In Japan, the government is privatizing the entire university system in part because they want Japanese universities to become economic catalysts, like their U.S. counterparts.

The conventional wisdom is that American universities transfer technologies more rapidly and more effectively than their European counterparts. However, a closer look at the cultural differences, the fragmentation of patent laws in Europe, and the widely differing regulatory framework (including the lack of a grace period) by Schmiemann and Durvy (2003) has shown that European academics are not that different from their American counterparts. The technology transfer function at European higher education institutes and research organizations, however, needs to get much more visibility, enhanced public policy support, better credentials for the professionals working there, and a professionally managed network to benchmark experiences and to exchange good practice. Policies to accelerate the commercialization of academic research now play a central role in U.K. government strategies for promoting regional economic development and enhancing national competitiveness (e.g. USHSC 1998; OST 2002; European Commission 2004ab). In addition, the European Commission is committed to taking its share of related responsibility and has recently fostered the PROTON network of European technology licensing offices. An intense discussion on the (re-)introduction of a grace period has recently begun across Europe. Additionally, some EU member states have abolished the professor's privilege to patent discoveries and their universities will consequently soon take up patenting on behalf of the institutions. It is not unlikely to expect trends similar to the U.S. after the changes to their regulatory framework in the 1980s.

Academic Knowledge Transfer via Highly Qualified Personnel (HQP)

Among the key contributions that publicly-funded universities make to economic growth in the knowledge-based economy are the performance of research and the training of highly qualified personnel. Many studies of the economic benefits of publicly-funded research highlight the role of skilled graduates as the primary benefit that flows to firms from the government's investment in scientific research. New graduates, who have had the opportunity to participate in the conduct of basic research, enter industry equipped with training, knowledge, networks and expertise. They bring to the firm knowledge of recent scientific research, as well as an ability to solve complex problems, perform research, and develop ideas. The skills developed through their educational experience with advanced instrumentation, techniques and scientific methods are extremely valuable. Students also bring with them a set of qualifications, helping set standards for knowledge in an industry. Senker (1995) suggests that graduates bring to industry an 'attitude of the mind' and a 'tacit ability' to acquire and use knowledge in a new and powerful way. Nelson (1987) also notes that academics may teach what new industrial actors need to know, without actually doing relevant research for industry. Basic techniques in scientific research are often essential for a young scientist or technologist to learn to participate in the industrial activities within the firm. Gibbons and Johnston's (1974) research in the 1970s demonstrated that students provide a form of benefit that flows from research funding. Studies by Martin and Irvine (1984) in the 1980s also showed that students trained in basic research fields, such as radio astronomy, move into industry over time and make substantial contributions. As such, there is a critical need to maintain, support and strengthen this crucial link between student training and government-funded basic research. Students provide a key transfer mechanism for the benefits of public sector funding to be channeled into industry and the broader society. However, according to a survey of Ph.D. recipients conducted by the ACS Committee on Professional Training published in 2000, one criticism of Ph.D. programs is that they could do a better job of preparing graduates for a career in industry.

Industrial post-doc positions serve as an important transition between academic training and industry. In many cases high profile companies such as Genentech or other industry leaders have adopted industrial post doc training programs to help assimilate the knowledge. The statistics on industrial post-docs from both the American Chemical Society and the National Science Foundation are sparse (Marasco 2003). A total of 48 people in industrial postdoctoral positions were identified through the annual ACS survey of new graduates between 2000 and 2002. Most of the industrial post-docs surveyed were working in development and design, research, or management. The most common employer was the pharmaceutical industry, followed by professional services and research institutions, and hospitals or clinical labs. The median salary reported during this period was $34,000. Data from NSF are even less descriptive. The best source of information is the Survey of Doctorate Recipients (SDR), which provides demographic and career history information about individuals with Ph.D.s. SDR is a sample survey that includes only US-educated post-docs and excludes foreign post-docs who earned doctorates outside the US. The NSF's Survey of Earned Doctorates, which is a census of people who receive research doctorates from US institutions, asks only about post graduation plans for further research. According to Joan S. Burrelli, a senior analyst in the Human Resources Statistics program at NSF, the number of industrial post-docs in chemistry is simply too small to analyze in any meaningful way. Out of the 1,800 chemistry (except biochemistry) post-docs that were identified by the 2001 SDR, just 170 were in industry. Most of them worked in biotechnology, health services, and research.

In the UK, the Co-operative Awards in Science and Engineering (CASE) studentship program of the UK Research Councils provide one example of wider efforts internationally to encourage so-called ‘knowledge transfer’ and thereby harness publicly supported university research more closely to the goals of national competitiveness, regional economic development and local regeneration (Demeritt & Lees 2005). The CASE program is designed to provide participating PhD students with the transferable skills and applied research experience to make them employable beyond the academy. The ESRC, in particular, sees the ‘collaborative awards scheme linking academic and non-academic partners in the training of PhD students’ as crucial to ensuring ‘that future social scientists . . . have the skills to work in a non academic as well as an academic environment’ (ESRC 2004). Likewise, in its own, in-house review, the Engineering and Physical Science Research Council (EPSRC) judged the success of its own CASE program partly in terms of its ability to increase ‘the number of students immediately taking up industrial careers’ (Holtum 2003).

Recent studies have also identified that finding and retaining talent is a critical factor influencing the development of clusters and the growth of dynamic urban economies. Locations with large talent pools reduce the costs of search and recruitment of talent – they are also attractive to individuals who are relocating because they provide some guarantee of successive job opportunities. According to Florida (1999), numerous executives confirmed that they will "go where the highly skilled people are." Highly educated, talented labor flows to those places that have a 'buzz' about them – the places where the most interesting work in the field is currently being done. One way to track this is through the inflow of so-called 'star scientists', or by tracking the in-migration of tomorrow's potential stars (post-docs). In their path-breaking research on the geographic concentration of the US biotechnology industry, Zucker and Darby (1996) document the tendency of leading research scientists to collaborate more within their own institutions and with firm scientists located close by. As a consequence, "where and when star scientists were actively producing publications is a key predictor of where and when commercial firms began to use biotechnology."

Another approach, employed by Florida and colleagues (Florida 2002, Gertler et al 2002) utilizes a more broadly defined measure of 'talent', and documents its strong geographical attraction to the presence of other creative people and activities locally. In-bound talented labor represents knowledge in its embodied form flowing into the region. Such flows act to reinforce and accentuate the knowledge assets already assembled in a region. Ultimately, the most valuable contribution that universities make to this process is as providers of highly skilled and creative members of the labor force and attractors of talent. Learning processes are eminently person embodied in the form of talent. According to Florida (1999), "universities . . . are a crucial piece of the infrastructure of the knowledge economy, providing mechanisms for generating and harnessing talent." This means that the role of public policy in stimulating economic development, particularly as it applies to the research-intensive universities, is critical.

Basic university research advances fundamental understanding and provides a substantial rate of economic return through the preparation of a highly skilled workforce, contributing to the foundation of many new technologies, attracting long-term foreign (and domestic) investment, supporting new company development and entrepreneurial companies and participating in global networks. Government funding and programs are the primary support for these activities.

The cases where governments have established a cluster by fiat such as Science Park in Taiwan or the Bio-Regio clusters in Germany do not always generate mature, innovative and profitable clusters. In many cases, the attempt to artificially establish a cluster where none existed previously has resulted either in failure or as a completely different type of cluster than initially envisioned. A good example of the latter is New Jersey's attempt to create a Silicon Valley high tech sector along the turnpike that eventually resulted in a limited research consortium (Leslie and Kargon, 1997). Cortwright and Mayer (2001) conclude that there is no general set of conditions that generate particular industrial clusters in the U.S, rather there appears to be a unique factor associated with each. An alternative view is that cluster formation is a process – a complex self-organizing process that is predicated on the actions of entrepreneurs and their symbiotic relationship with their local environments. The cluster and the characteristics of the cluster therefore emerge over time from the individual activities of the entrepreneurs and the organizations and institutions that co-evolve to support them.

New economic development strategies may be informed by recognizing the endogenous nature of regional industrial development. A literature is developing that considers the formation of clusters and the processes by which local economies are able to garner the rewards of investments made in resources that support innovation in Markusen's (1996) typology, to make the transition from slippery to sticky. Universities certainly figure prominent in cluster formation however there are multiple reasons why knowledge transfer from academic institutions may not be effective.

Why Knowledge Transfer does not Work – Incomplete

1) Universities are necessary but not sufficient for economic development.

2) Universities typically lag rather than lead economic development.

3) Lack of Absorptive capacity in local area: Absorptive capacity refers to the ability to assimilate and replicate new knowledge gained from external sources (Cohen and Levinthal 1990). Absorptive capacity results from a prolonged process of investment and knowledge accumulation within the firm, and its development is path dependent (Mowery et al., 1996). Therefore, the persistent development of the ability to absorb knowledge is a necessary condition for a firm's successful exploitation of knowledge outside its boundaries. A parallel line of research in the broader technology-transfer literature suggests that possession of relevant technical skills facilitates inward technology transfer (Rosenberg and Frischtak 1991; Agmon and von Glinow 1991). Gambardella (1992) further argued that higher levels of absorptive capacity would improve a firm's ability to exploit sources of technical knowledge outside its boundaries. Firms with a high level of absorptive capacity are likely to have a better

understanding of the new knowledge and to harness new knowledge from other firms to help their innovative activities (Tsai 2001; Makhija and Ganesh 1997). Without such capacity, firms are hardly able to learn or transfer knowledge from outside. The ability to benefit from investments in higher education will depend on the absorptive capacity of local firms.

4) Lack of alignment of local economy and local academic institutions.

5) Institution specific factors.

Reflective Conclusions

The prime actors who realize value from innovation are private firms. Yet universities, technical colleges and the range of post-secondary institutions are important to the activities of private firms. At the most simplest, institutions of higher education provide skilled labor and ideas as inputs to firms' production function. This is a reductionist view that ignores the traditional role of universities as public entities that provide intellectual training and discourse, address market failures by provide public goods, develop new disciplines and cultivating the development of novel ideas.

The role of institutions of higher education is evolving. There are many pressures that force academic institutes to collaborate with private industry and to protect intellectual property. Often, these two goals are in conflict. For example, more stringent IP protection may place universities in direct competition with firms. In addition, to the extent that there is a market for academic IP public support may be eroded.

It is also important to remember that innovation also encompasses incremental improvements to existing products or processes. Indeed, the vast majority of innovation may be attributed to minor improvements, adjustments, and refinements to existing products, manufacturing process and organizational practices. While not particularly glamorous, these activities add economic value and, in sum, provide a basis for sustained competitive advantage. In addition, while science is important to innovation, new ideas are frequently suggested by individuals who work on the shop floor, who use products, and who supply machinery or materials. Indeed, innovation spans the spectrum of industrial activity. The view that innovation is limited to new science-based or so called high technology industries is myopic, as it ignores the equally transformative nature of innovation in existing mature industries that are already in place.

Bibliography

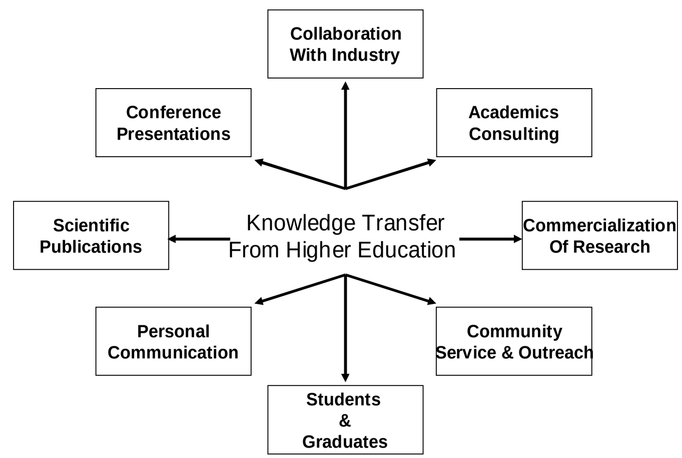

Figure 1: Knowledge Transfer Mechanisms from Academic Institutions

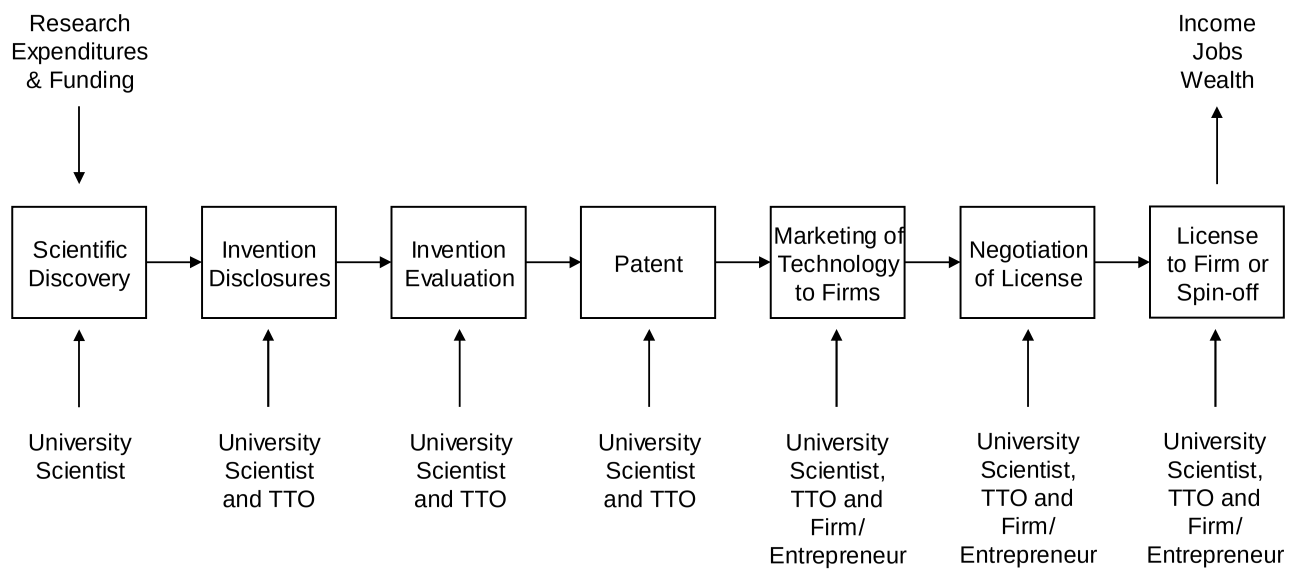

Figure 2: Flow Chart of how technology is transferred from an academic institute

Table 1. Key stakeholders, their roles and representative motives in the transfer of technology to the private sector

Stakeholder	Actions	Primary motive(s)	Secondary motive(s)	Organizational culture
Academic scientist	Discovery of new knowle dge	Recognition within the scientific community—publications, grants (especially if untenured)	Financial gain and a desire to secure additional research funding (mainly for graduate students and lab equipment)	Scientific
Technology transfer office (TTO)	Works with faculty members and firms/entrepreneurs to structure deals	Protect and market the university's intellectual property	Facilitate technological diffusion and secure additional research funding	Bureaucratic
Firm/entrepreneur	Commercializes new technology	Financial gain	Maintain control of proprietary technologies	Organic/entrepreneurial

Table 2. Review of the Key Drivers Affecting University TTO Efficiency

Focus	Author	Paper Title	Data Used in Study	Key Findings
Organization, Culture and Location	Friedman & Silberman (2003)	University Technology Transfer: Do Incentives, Management, and Location Matter?	Literature review and analytical models developed from AUTM data	Analysis strongly supports four factors not university technology transfer: 1) The expe Greater rewards for faculty involvement in support of technology transfer and 4) The l high technology firms.
Communication	Daghfous (2004)	An empirical investigation of the roles of prior knowledge and learning activities in technology transfer	Literature review and analysis based on a survey of 4600 projects undertaken at Penn State.	A significant positive relationship was foun during the development and implementatic benefits to that firm from the project.
Organizational	Siegel et al (2004)	Toward a model of the effective transfer of scientific knowledge from academicians to practitioners: qualitative evidence from the commercialization of university technologies	Based on 55 structured interviews of 98 UFTT stakeholders associated with five US research universities	Determined that there are numerous impe informational barriers among the three key and firms/entrepreneurs), 2) TTO staffing a for faculty involvement in UFTT. Two some have decided to circumvent the formal UF increase the quantity and quality of basic r
Organizational Incentives - TTO	Siegel et al (2003)	Assessing the impact of organizational practices on the relative productivity of university technology transfer offices: An exploratory Study	Quantitative Analysis was Based on 1997 AUTM Report (DEA and SFE), Qualitative Analysis based on 55 interviews of 98 entrepreneurs, scientists, and administrators at five research universities.	Based on our qualitative evidence, we beli reward systems for faculty involvement in U and 3) actions taken by administrators to e universities and firms.

Organizational Form-TTO Managers	Bercovitz et al (2001)	Organizational Structure as a Determinant of Academic Patent and Licensing Behavior: An Exploratory Study of Duke, Johns Hopkins and Pennsylvania State Universities	Case Study from three Universities	The analysis treats the organizational struc transfer office as an independent variable f institutional patenting, licensing, and spons
Organization-University Researchers	Jacobson et al (2004)	Organizational Factors that Influence University-Based Researchers' Engagement in Knowledge Transfer Activities	Extensive Literature Review, with a Canadian Focus	Researchers working in Universities report translation activities. The groups analysis o organizational policy and practice—promot knowledge transfer orientation, and docum engagement in knowledge transfer.
Culture	Feldman & Desrochers (2004)	Truth for its Own Sake: Academic Culture and Technology Transfer at Johns Hopkins University	Historical Survey of Johns Hopkins and comparison with current literature.	The institution and its culture largely deterr research to the public.