CHAPTER

Knowledge Diffusion: The Prospects for More Productive University-Industry Partnerships

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Over recent years, technology has dramatically changed how industrial corporations partner with one another. Yet, there has been little change in the relations between universities and industry. In this paper we explore how technology and market forces have facilitated a fairly dramatic change in industry-industry partnerships over the past 15 to 20 years, and we ask whether those influences can engender more productive university-industry relationships. In the U.S. and Europe there are increasing concerns about innovation and the ability of those nations to compete in the global marketplace. University-industry partnerships should be a high-leverage contributor to innovation, and, therefore, to national economic strength. So, productive university-industry partnerships have very high value. And there are too few of them.

Partnering relationships between corporations have changed in quite remarkable ways. For example, some companies now outsource their customer care and maintenance support service, and rely on just-in-time supply by subcontractors. Some outsourcing involves companies off-shore. Corporations focus to a greater extent on exercising their competencies and they rely on partner organizations for support. A hallmark of such corporate relations is a much higher level of trust. This is evident because these new-relationship companies deliberately position themselves so that their ability to perform in

the marketplace is utterly dependent upon the timely performance of partner corporations for whom there may be no back-up. Trust has always been a necessary element of university-industry partnerships, but it has not always been sufficiently present.

Technology is a first order enabler of new ways to address markets; perform customer care; deploy non-stop, 24/7 services; deliver one-of-a-kind, customer-tailored product configurations; deliver products just in time and collaborate in deep ways. To a great extent the new kinds of industry-to-industry relationships are enabled by the adroit use of information technology and communications. Yet, it is market forces that frame the relationships.

The Colloquium in Glion seems an appropriate venue in which to ask: do these new forms of corporate partnership give new scope or opportunity for university-industry partnerships? Do the new openness and trust in partnerships that are now a hallmark of today's industry carry over to new and better kinds of relationships between universities and industry? Are there opportunities for more effective partnerships between these disparate organizations than in the past?

NEW MODES OF INTERACTION

In this section we address the technology and the new modes of interaction that contribute to new types of corporate relationships. One enabler of partnerships is the ability to share data about products and services between partner corporations. For example, engineers across multiple organizations can share common engineering drawings that can be updated in real time by any partner as permitted by disciplined access control, and even collaboratively updated. Remote, (near) real time monitoring and control of instruments permits "corporately separate" individuals to remotely participate, monitor, or even control, some element of the laboratory or manufacturing activity of another partner. Computational simulations of natural and human-induced phenomena permit geographically separated individuals to collaborate in the study of on-going activity in industrial space or in a laboratory. Engineering data from one site can be fed into simulations in another in near real time.

Collaboration through remote data sharing has the added property that what is shared is just that which is represented in the data. Engineering specifications and drawings may not make visible proprietary aspects of the manufacturing or fabrication process by which the product is built. Sharing of data can be judiciously restricted and one company can conduct parallel activities with multiple corporate organizations without divulging the data of one partner to another. This aids a company in protecting what it considers proprietary by avoiding "too many" physical visits by personnel from supplier partners. Likewise, remote collaboration via shared data and shared visualization

permits a participant to stay at their home site and interact with remote colleagues on a low-overhead, even no-notice, basis.

The accuracy of shared engineering data makes it possible for one company to fabricate a component that is within tight specifications. It is shipped to a partner who can efficiently integrate that component into a larger physical system due to tight control of both system and component manufacture. So the new modes of interaction are not limited to information-based collaboration; information technology facilitates more efficient physical interaction as well.

Worldwide communications for tele-collaboration are cost-effective. The research universities, as well as industry, already have high-speed network and computing infrastructure in place and in routine use. A new relationship need not bear the cost of any unique communication infrastructure to underpin it.

Information technology has led to another change — one organization can capture domain expertise, processes and techniques in software (digital tools) which can then be used by others, even users who do not understand the inner working of the software. This new vehicle for knowledge diffusion allows organizations to exchange expertise and knowledge in a potent form. Industry may view digital tools that they develop as proprietary and restrict sharing to partners. University researchers typically post and promulgate such digital tools and data resources openly. When source code and not just binary code is available, such tools are described as "open source". This open promulgation of research results in a digital form that allows others to perform similar experiments or to replicate (or not) the results of the original researcher. Digital tools are yet another way that information technology facilitates collaboration and productivity in partner organizations — whether tool sharing is restricted, or whether open source code is posted publicly.

All the technology-based enablers for industry-industry partnerships should be equally as effective for university-industry partnerships. Remote sharing of data and collaboration are particularly helpful because industry is typically reluctant to send their best talent to work on longer-term research collaborations. Technology permits intermittent and remote interaction.

CORPORATE R & D LABORATORIES

In the U.S. when "globalization" became a reality of business in the early 1990s, substantial cut-backs of some large, premier research and development (R & D) laboratories began. Not even the most prestigious were spared. General Motors, Texaco, IBM, Bell Laboratories and Xerox were only a few corporations that substantially downsized their laboratories. Industry felt that it could not support the cost of those laboratories in the more competitive global markets that they necessarily had to address. As a result, less research and

advanced development are conducted by these corporations, and they typically emphasize development over research. In the U.S., these laboratories have not been rebuilt to their former states.

In the past few years, at least a few high-tech companies have sited divisions of their corporate R & D laboratories in the locale of university research activity. Intel has opened a laboratory near Carnegie-Mellon University, University of California-Berkeley, Cambridge University in the U.K., and the University of Washington in Seattle. It is even more of a change that some corporations are locating satellite R & D laboratories not just in the country of their headquarters, but around the globe. Microsoft Research Laboratory sites divisions in what appears to be a more market-conscious way, placing R & D laboratories in Beijing, China, Silicon Valley, Cambridge in the U.K., and Bangalore, India. Mitsubishi Electric Research Laboratories include a Telecommunication Lab in Rennes, France, a Visual Information Lab at the University of Surrey in the U.K. and the long-standing Research Lab in Cambridge, Massachusetts. All have university relationships with at least those universities in the local geographic vicinity. Today, corporate research laboratories are located internationally, not just in the home country of a corporation. Technological innovation knows no borders.

That may indicate that corporations can be expected to be more amenable to building university partnerships with any strong university, not just those in the country where their headquarters are located. The ease with which trust relations can be built up with an individual university will play a role in the development of partnerships. Intellectual property arrangements can be an impediment to building a trust relationship. This will be discussed later.

Sematech, born of faltering U.S. microelectronics market share, created a successful research and development activity with many partner corporations in the semi-conductor business, as well as their supplier companies. After declaring the success of Sematech, the Semiconductor Industries Association told the U.S. government that it no longer needed the Sematech funds (being routed through D.A.R.P.A. until the mid-1990s). The semi-conductor industry and Department of Defense then formed a follow-on partnership for basic research. The industry funded $2 for every government matching dollar. The purpose of the government participation was not so much as a source of funds, but as a participant who could insist on the performance of basic research over near term development (Barrett, 1996). Initial projects were determined by a D o D sponsored workshop in the mid-1990s attended mainly by the university researchers.

High-tech industry critically relies on innovation which — over the long run — is grounded in basic research. With the current structure of industrial R & D laboratories, it is difficult to document whether there is less of a reservoir of basic research available to high-tech companies, whether there are less

or more substantive basic research relationships between university and industry, and whether the pipeline of students trained in the context of truly long-term basic research is of increasing or decreasing quality, particularly in rapidly advancing disciplines. It is also difficult to determine whether high-tech industries have access to an adequate pipeline of basic research. The bottom line is that there is need born of competition for industry to acquire appropriable research and the derivative innovation from somewhere, if not from in-house laboratories. And the most stable and robust source of basic research, at least in the U.S., is the research universities. A few selected government laboratories, such as the Naval Research Laboratory, are reliable sources of research results. But, for the most part, the government laboratories are focused on mission and related technology application. There is no rising alternative to the research universities as a source for both research ideas and the new graduates with expertise that advances innovation.

RESEARCH INFRASTRUCTURE

Financing affects the willingness for organizations to collaborate. In particular, the cost of the necessary laboratory infrastructure for the specific research to be conducted must be found if the laboratory is to function. Both in universities and in industry, the cost of laboratory equipment has increased in most areas of engineering, science and medicine. Researchers in physical science and engineering explore increasingly smaller and larger scale phenomena — nano-science to galaxies. Experiments are more complex as they move from 2-D to 3-D analysis (e.g. 2-D DNA string discovery to 3-D protein folding). The equipment to support such exploration is often more sophisticated and more expensive. The resulting financial reality has given rise to an increasing number of virtual research centres, particularly in the research universities in which researchers from multiple universities share equipment. The National Science Foundation supports numerous such centres across fields as disparate as earthquake engineering, nano-scale engineering, and astronomy. A virtual centre should as easily accommodate a corporate partner as a university partner. So, the trend to geographically distributed research collaborations and shared research infrastructure should positively impact the consideration of university-industry partnerships.

RESEARCH COLLABORATION

Some research questions have been out of reach of university researchers. This is especially true when the research involves engineered systems such as long-term performance of diesel engines in actual use, the behaviour of a molten

material within a controlled manufacturing process, or retail marketing inventory management. Industry has direct access to the relevant data.

Today, information technology makes possible laboratory access to ongoing social and business activities. Industry data could be made available to university researchers — the technology supports such sharing of information. However, again the issue of trust arises. A corporation will only share such data — which is likely considered sensitive, if not proprietary — if the two organizations trust each other. Numerous such trust relationships exist between a company and a trusted supplier. There may be more openness to establishing such relationships, if industry believes that it is receiving value from the relationship with a university.

Another gradual change is that "we are teaching more and more about less and less" (Mead, 2003). Individuals are educated to be expert in narrower and narrower fields as the amount of knowledge in each field increases. As a result, research collaboration is becoming increasingly interdisciplinary in order to have all the necessary expertise available. Over the past several decades — in the U.S. at least — there has been an increase of university research collaborations that involve researchers from multiple disciplines. Concomitantly, there has been a rise in the number of university-university collaborative centres that tackle problems deemed to be too large for one university. The imperative to collaborate across disciplines incrementally grows over time. When a company focuses its efforts on just its "core competencies", its need for experts in related fields increases. This too augurs well for university-industry partnerships.

Anecdotally, larger university research efforts increasingly appear to motivate their research by stating a need to solve social problems, e.g. predicting earthquakes and ameliorating damage from them; weather prediction; aiding ageing populations to live at home longer; and protecting the soldier. Whether this is driven by government funding focused on short-term objectives, or by the researchers' own curiosity, such rationales seem more abundant. Industry always has such rationales because their overall objective is to produce a better product or service. So, one might conclude the university researchers are now more comfortable with stating application objectives for their research, where sensible. Such motivations need not limit the long-term nature of research, if the motivations are suitable structured.

I conclude that many of the forces or trends affecting university research can be viewed as supportive of future university-industry collaboration. There is, I believe, a genuine increase in the opportunity for richer and more productive partnerships.

Of course, the most profound partnership of all is that industry hires the students that come out of the research universities. Those students carry new knowledge into the corporation, and over time influence how the corporation

adapts. That partnership does not seem to be changing, except that both industry and universities are more "internationally minded".

THE BASIS FOR PARTNERSHIPS

Now I want to turn to the fundamental relations between the organizations and the individuals involved in a university-industry partnership. First, such a partnership can work very well; there is a long history — at least in the U.S. — of university-industry partnerships. There are diverse staffing and funding arrangements. Industry may provide employees to directly participate with university researchers. Faculty may consult with a company, sometimes taking extended absences from the university to work at a corporate location. But a common arrangement is a partnership that only involves industry funding research in an existing university laboratory with no joint staffing. These partnerships are weak if the industry funding only pays incremental costs to an ongoing activity that is funded from other sources.

Genuinely close university-industry partnerships are typically more difficult to establish and maintain than industry-industry partnerships because the cultures of the two kinds of organizations are different and their reward systems and objectives diverge. A few specific reasons for difficulty in university-industry relationships include:

- industry is typically focused on the short-term development of a next product; universities are focused on discovering new knowledge for its own sake;
- university researchers seek the reward of recognition by their peers in the larger research community based on rapid and open publication of their research findings; industry researchers are rewarded by the corporation when they advance corporate products and services;
- industry is often unwilling to pay more than incremental research costs, while the university researchers attempt to amortize laboratory recapitalization across all research activity;
- industry needs to protect its ability to appropriate, perhaps uniquely, the ideas that derive from research; university researchers want to publish ideas broadly; wrangling over intellectual property is routine; and
- university researchers want to protect their ability to team with multiple corporations; industry needs to protect its proprietary information.

One influence on the formation of such partnerships in the U.S. is the appearance of a "new player". This is the University Patent Foundation or Technology Transfer Foundation. These organizations came into being after

the passage of the Bayh-Dole Act that granted universities ownership of the intellectual property that their researchers developed. Essentially, all U.S. research universities have such an organization. These foundations typically hold the intellectual property of the university and are in business (1) to proactively ensure that a university's intellectual property is exploited for the good of the nation, and (2) to derive income from it. Consequently, the formation of a university-industry partnership involves not just the interests of the researchers and the university "sponsored programs office", but a foundation whose objective is to create wealth based on intellectual property. Anecdotally, industry complains that negotiation over intellectual property rights has become more complicated and constitutes the greatest impediment to university-industry partnerships.

The return of these foundations is mixed. In select cases universities have earned tens, or hundreds of millions, of dollars on a single "home run" patent. But such return is rare. Some foundations barely pay, or do not pay, their own expenses. The Association of University Technology Managers conducts a survey of results of technology management at research universities. Their A.U.T.M. Licensing Survey: Fiscal Year 2003 report can be found at www.autm.org. It reports on invention disclosures, patent applications, patents issues, licences/options executed, and new companies created. They report that 374 new companies were created in 2002 in the U.S. that depended upon university licensed intellectual property. These foundations do aid in the creation of new companies by faculty, and they fund both patenting and license marketing, activities that faculty may not pursue.

The 2003 report indicates that overall the A.U.T.M. universities that responded to their survey expended $31 billion of the $36 billion expended on research in the U.S. in 2002. The foundations earned $1.3 billion or roughly 4% compared to one year of research funding expended by the universities. Of course, part of this income must pay the cost of the technology transfer enterprise. So, return after expenses will be lower. This percentage return on investment is not particularly high. However, the patent foundation organizations are for the most part relatively new and still have not had time to mature. One thing is certain — the advent of the Bayh-Dole Act complicated the formation of university-industry partnerships in the United States.

THE AUDACIOUS IRISH

In this section we explore the climate for creating partnerships and whether a small population — in this case a small nation — can more productively and effectively nurture university-industry partnerships that out-perform their competition. Ireland provides an intriguing case of study of a country seeking to make a material change in university-industry partnerships.

Twenty years ago Ireland was a struggling agrarian nation with an economic growth rate just above 2%. By the late 1990s (1994 to 2000) Ireland had transformed itself into the Celtic Tiger, a nation with economic expansion of 9.3% that led the world, eclipsing even the Asian Tigers as measured by growth rate. Their strategy for aggressive economic growth relied upon low corporate tax rates, cooperative unions, and an educated, English-speaking workforce. Ireland established itself as an attractive place for corporations to site new manufacturing and fabrication plants. In 2004 Intel's largest semiconductor plant outside America was upgraded and commenced manufacture of an advanced line of components. Nine of the world's ten largest pharmaceutical manufacturers have plants in Ireland, as do Dell and Apple. Ireland receives one third of all foreign direct investment into Europe in the areas of health care and pharmaceuticals in recent years. Ireland's attraction in the 1990s was not technology-based, but financial, with an attractive business operations climate.

Ireland is a nation of 4 million souls, less than the population of Los Angeles, California or Toronto, Canada, and half that of New York City. Ireland offers an excellent example of how a small nation, a small population, can craft and execute a strategy that changes the relation between industry and a nation.

Such aggressive growth above 9% is difficult to sustain; no country has done so for more than a few years. In the late 1990s India and Eastern Europe could offer lower costs and gave Ireland competition that bled off investment.

So, what is Ireland's follow-on strategy to attempt to maintain vigorous economic expansion? It is to further develop their good education system to produce knowledge workers at an advanced level, and to establish the Irish universities at the forefront of research in information technology and biotechnology. Ireland's "round two" strategy calls for attracting more than manufacturing plants; they want to attract research and development centres of high technology companies to locate in Ireland with direct collaboration with the Irish universities. So, the government has set as an objective to grow world-class research activities inside their universities (third level organizations).

Ireland did not start with the best research universities in the world or with many large, indigenous Irish companies. The Irish K-16 education is rated highly. The government increased the number of students attending college substantially between the mid-1990s and 2000. Their strategy is indeed audacious. Were the U.K., the U.S. or a few other nations to field such a strategy, one could argue that they would start with world-class research universities.

A keystone of the "round two" Irish strategy is Science Foundation Ireland (S.F.I.). Modelled after the National Science Foundation in the United States, this government agency funds basic research in information technol-

ogy and biotechnology in Irish universities. The author served on the Board of Trustees of S.F.I. for the first three years of its existence as we were defining its principles of operation.

Grants are awarded based on international peer review. On a per capita basis, Ireland is investing more in research than the United States. S.F.I. has invested not just in principal investigators and in university research centres, but in creative university-industry partnerships. Recall, the objective is to attract industry R & D laboratories to Ireland, and to have them co-locate with universities, where appropriate. Executing a strategy that China, Taiwan and other countries have successfully used, Science Foundation Ireland has been particularly successful in bringing researchers with ancestral ties to Ireland back to Ireland permanently or as visitors.

There are indications that the overall Irish strategy is having a positive effect. Hewlett Packard, Servier, Siemens, and Proctor and Gamble all have entered into partnership in major research centres with Irish universities since 2002. Intel has a new research activity in nano-science with Trinity College Dublin, and Bell Laboratories is establishing a centre for research in telecommunications and supply chain technologies in Ireland.

These knowledge-based partnerships are based on small numbers of people, knowledge and expertise in pursuing new research ideas. The audacious and apparently successful Irish demonstrate that small groups — it need not be a national activity — can exert large economic leverage when the course that they chart is focused, financed and complementary to the interests of ever-evolving industry. These university-industry partnerships have the advantage that the education of the next generations of Irish researchers is intimately entwined with their operation. The Irish expect the process to be relatively self-sustaining.

CONCLUSION

The question addressed in this paper is whether the climate for university-industry partnerships has changed, and whether it offers new opportunities. In summary, I think that the answers are "yes" and "yes". The above discussion argues that information technology coupled with market changes has opened industry to the possibility of new relationships. Of particular importance is the increase of the level of trust that is endemic in these relationships compared to relationships of two decades ago. A number of companies have made their ability to perform deeply dependent on the performance of their suppliers. Further, we pointed out that global competitiveness has led companies to focus on their core competencies, and to a reduction of corporate R & D capability. Yet high-technology companies need not just modest product increments, but new ideas that can underpin whole new product lines.

Technology innovation is the life-blood of high-tech corporations, especially as they are driven to compete globally, not just regionally. Industry has embraced new relationships with other partners. Is there an opportunity for more and closer university-industry partnerships? Can a company invest such trust in a relationship with a university in order to gain a pipeline of new ideas at a stable and rapid rate as input to product innovation? It is the university whose core competency is research. My hypothesis is that if corporations are entering into much more intimate and dependent relationships with other corporations, then it is worthwhile to take a fresh look at the potential for future university-industry partnerships.

In the minds of some, the U.S. and Europe are losing their innovative advantage. The European Union has re-affirmed the Lisbon Agreement which states an objective of becoming the most innovative and productive economy in the world by 2010. One symptom of U.S. slow-down is that in 2003, America ceased to be the world's leading recipient of foreign direct investment, eclipsed by China. This is one measure of how markets judge the promise of competing nations. The U.S. has no clear statement of economic objectives and action that is comparable to the Lisbon Agreement.

If nurturing a knowledge-based economy that emphasizes university-industry knowledge partnerships is a sound strategy for a nation like Ireland, it may be a sound strategy for other nations. Both Europe and the U.S. have a culture of investing government funds in research and development, and in their universities. This positions them to be able partners of industry.

Can even a small national effort make a difference? The Irish accomplishments argue that it can. In his book, *As the Future Catches You*, Juan Enriquez, of Harvard University, says: "The future belongs to small populations who build empires of the mind." (Enriquez, 2001).

University-industry partnerships are a natural mechanism to use to relate basic research to industrial innovation, and speed knowledge dissemination. One major sticking point that we have not yet addressed is how appropriable research results are to a company's product lines and sales capability. It is industry's concern that they will not be able to appropriate the results that come from research, or not be able to do so in an acceptable time period. With government and the universities involved as co-investors, the opportunity for appropriable return should increase.

If the U.S. or Europe became seriously concerned about the productivity of their economies, then governments could reconsider both incentives aimed at encouraging innovation. For example, R & D credits — essentially government subsidies for industry to invest in R & D — could be an increased funding source for partnership with universities. The opportunity for more productive and more creative university-industry partnerships has never been greater, and in Europe and the U.S. the need for translation of new ideas into new products is greater than ever before.

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