April 15, 2007

Federal Reserve Bank of Cleveland

How Much U.S. Technological Innovation Begins in Universities?

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Technological progress has been the key to improved living standards, but how and where do new ideas get their start? The answer might give us some insight into how we can support greater innovation. Some suggest universities have been an important source of innovative technology. A look at the people involved in the development of patented technologies can give an idea of how much innovation originates in universities.

In developed economies, technological progress is a key route to improved living standards, and universities are thought to be important sources of innovation in the economy. The U.S. patent records offer a rich set of information with which to examine the flow of technological know-how from university laboratories to industry.

Using information gleaned from patents, a number of interesting questions can be addressed: How significant is the flow of technological know-how from university to industry? Has it changed over time? Which industries benefit the most from university research? What sorts of firms are best equipped to access university research?

We examine these questions using data from 1985 to 1997 (the last year for which we have reliable data), a period that coincides with an unprecedented increase in innovation and patenting in the United States.

Knowledge Flow from University to Industry

How we seek to answer these questions depends on our belief about how knowledge transfer between the sectors takes place. Certainly some economically important science flows from universities to industry via the conventional means of scientific communication. Industry personnel read scholarly publications written by university scientists, and they absorb university research through attendance at academic conferences and lectures. Researchers studying technology transfer believe, however, that much new and valuable university-produced knowledge is not easily transmitted except through sustained, close interaction with university researchers.

New knowledge initially is known only to its discoverer or discoverers. If knowledge is not incremental—that is, distant in some sense from pre-existing knowledge—it may not be easily connected to old, familiar science and thus difficult to codify. This kind of knowledge is naturally excludable and tends, at least initially, to remain lodged in the human capital of the discovering scientist or scientists.

This "tacit" knowledge is passed to the noninitiated only when they have the opportunity to observe and query the discoverers at the scientific bench over a sustained period of time. Coemployment and collaboration may create those kinds of transfer opportunities.

Thus, to tap some kinds of university know-how, firms must employ or seek collaboration with university researchers. We use U.S. patent data to study the role of research personnel as a pathway for the diffusion of ideas from university to industry.

Tracking Inventors

The inventors behind the patented invention are listed on each patent, as is the firm, government organization, or university to which the patent is assigned. With our colleague Sangjoon Lee, we matched inventor names on patents to construct a panel data set of inventors that contains the patents in each year of the inventors' careers.

ISSN 0428-1276

This enables us to identify for each inventor when and how often he or she is innovating for university and industry assignees (the legal entities to which the intellectual property right is awarded). For each patent assigned to industry, one can tell whether its inventors had previously appeared as an inventor on a patent assigned to a university. Appearing on a patent assigned to a university is evidence that the inventor has had exposure to university research, either directly as a university researcher or through some form of collaboration with university researchers.

We also link a comprehensive database on degrees awarded in North America and Europe to the inventors to establish whether the inventor has an advanced degree (doctorate, usually), another measure of exposure to university research.

Patents list the assignees, and they are, in most cases, the employers of the listed inventors. For assignees that are publicly traded and in the pharmaceutical and semiconductor industries, two of the most innovative industries in the U.S. economy, we obtained data from the U.S. Securities and Exchange Commission. Thus for each of these assignee-firms, we know, for example, the firm's size, age, expenditures on research and development activities, and the scope of its operations (its number of product lines). With firm-level data, one can evaluate what makes some firms more interested in acquiring or more able to acquire the know-how produced in university laboratories.

We first consider the prevalence of patents granted to industry that list at least one inventor who had previously been named an inventor on a recent (less than ten years old) university-assigned patent. Being named on such a patent typically means the inventor was conducting research as a university-employed scientist in a university laboratory, or as a collaborator of such a scientist. Either way, the inventor with university research experience has had close, sustained contact with novel, specialized techniques and bodies of knowledge, much of which is difficult to access by the firm.

Where the Collaboration Is Closest

Between 1985 and 1997, the percentage of patents that name at least one inventor with university research experience rose economywide from 0.9 to more than 2 percent. Examination of the pharmaceutical and semiconductor industries reveals that results are not uniform across industries. Perhaps not surprisingly (and, as it turns out, by all of the measures that we examined), the pharmaceutical and semiconductor industries demonstrated higher-than-average interaction with university research.

Between 1989 and 1997, about 6.6 percent of patents in the pharmaceutical industry included at least one inventor with university patenting experience compared to about 1.9 percent in the semiconductor industry. In both industries, we find a substantial increase in the percentage of patents naming inventors with university patenting experience: from approximately 5.5 to 6.8 percent in the pharmaceutical industry, and from approximately 0.2 to 2.5 percent in the semiconductor industry.

Universities infrequently patented their inventions before the 1980s. So while it is possible that firms were interacting with university research in earlier years at the same rate as in later years, we do not detect it. In that case, the increase we observe in the use of inventors with university research experience is not a deliberate attempt to get at university techniques and knowledge. It is more so a natural consequence of the more numerous inventors with university patenting experience that occurred for reasons unrelated to industry's labor demand.

We do in fact find that two-thirds of the increase is due to the increased prevalence of inventors with university research experience. One-third is due to an increase in the likelihood that a university-experienced inventor was used by industry in 1997 compared to in 1985.

Perhaps a more direct measure of industry seeking out university-based science is the percentage of industry patents that include at least one inventor with an advanced degree (master's or doctorate degree in natural science and engineering). It is more direct because we know that an inventor with an advanced university degree has undergone a lengthy and intense period of university training. Some inventors that appear on university patents, on the other hand, may have been brought in on a collaborative basis and subsequently experienced little exposure to university sources of knowledge and techniques.

We find an increase in the percentage of patents granted to industry that name an inventor with an advanced degree from 6.9 percent in 1985 to 14.7 percent in 1997. The average levels over the period are higher in the pharmaceutical and semiconductor industries than in the economy broadly: the average is 33 percent in the pharmaceutical industry and 19 percent in the semiconductor industry. As we found with the university research measure, the rate of increase in the fraction of patents naming inventors with advanced degrees was positive in both industries, and it was higher in the semiconductor industry.

Finally, we consider the percentage of industry patents that cite a recent (less than ten years old) university patent. Patent applicants are legally obligated to disclose any knowledge they have of previous relevant inventions. The patent examiner then adds to the application any relevant citations omitted by the applicant. Thus, through the patent citations, each patent documents the "prior art" upon which the new innovation builds, and because we know each cited patent's assignee type, we know whether the prior art originated in university laboratories.

Like the previous measures, the citation measure rises over time. In 1985, 3.1 percent of industry patents cited university patents economywide. The measure increases steadily until 1995, when it achieves a rate of 8.4 percent, dropping off to a little under 7 percent by 1997. Qualitatively, this measure displays patterns that are similar to those of the previous measure. The measure's average level is higher for the pharmaceutical and semiconductor industries, but in both industries this measure approximately doubles over the 1985–95 period, though both show a bit of fall off through 1997.

Given that universities patented their innovations at lower rates in earlier years, industry access was not as apparent. However, the likelihood that a university patent is cited by industry is not subject to this problem. We find that the average university patent in 1995 is more likely to be cited in an industrial patent than the average university patent in 1985. Between 1995 and 1997, the citation rate falls to very nearly the citation rate in 1985, however.

Characteristics of Receptive Firms

What are characteristics of firms that make them more or less receptive to the kind of research emanating from universities? In our firm-level analyses, we find that firms with large research operations in both industries are more likely to access university research than firms with small ones, holding other measurable characteristics constant.

This suggests the presence of scale economies that give an edge to large or diversified firms in exploiting university know-how. Younger pharmaceutical firms are more likely to utilize inventors with university research experience. A firm's age does not seem to matter in the semiconductor industry. Empirical findings in other contexts suggest what economists call complementarity between skilled labor and capital; that is, capital equipment (machinery, tools) is more productive in the hands of skilled workers, and thus capital equipment and skilled labor tend to appear together in production. We find capital–skill complementarity as the use of university-research-experienced innovators (a kind of skilled labor) rises with the firm's research and development expenditures per inventor.

How Important Are Universities to Innovation?

The period under study witnessed unprecedented changes in the innovation rates in the United States. Between 1961 and 1984, the annual domestic patent application count in the United States varied within a narrow range of 59,000 and 72,000. After 1984, however, the annual patent application rate doubled, reaching 149,825 in 1999. The number of patents granted experienced a similar rise.

Our results suggest that technological transfer from university to industry may have played a role in the innovation explosion of the last two decades. We find economywide and in the very innovative pharmaceutical and semiconductor industries, in particular, that industry's use of inventors with past experience in university laboratory settings increased during the mid-1980s through the 1990s. Findings predicated on citation-based measures of industrial access of university research point in the same direction.

A number of questions remain unanswered and the focus of our (and other researchers') present and future work. Foremost among these is: What is the effect of hiring or collaborating with university-experienced scientists on the productivity and output of firms' research and development activity?

Patents represent more applied forms of research, and our patent-based measures likely imperfectly capture the transfer of the more-basic kinds of university knowledge to industry. Thus another important part of the research agenda is expanding measures of technology transfer. Industry and university scientists often collaborate in publishing scientific papers. Publication information is available over time and relatively easy to gather. Accordingly, collaborations on scientific publications may serve as a useful barometer of technological transfer of a more basic kind between the academic and industrial sectors. Answering these questions will help us better understand the role of university research in U.S. economic growth.

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