FRBSF ECONOMIC LETTER

Number 2004-32, November 12, 2004

Does Locale Affect R&D Productivity? The Case of Pharmaceuticals

As the U.S. economy becomes more "knowledge-based," the decisions that policymakers and firms make about spending on research and development (R&D) take on increasing significance. In making those decisions, an important dynamic of R&D to consider is that most innovations borrow heavily from prior or related work; this implies that enhancing the potential for such "spillovers" from one researcher's innovative efforts to another's could make R&D more productive.

A fundamental question for managers of firms and for policymakers, then, is whether such spillovers are more likely when R&D centers are geographically close. If so, then a firm manager may choose to locate R&D laboratories near other labs doing similar work; likewise, policymakers may want to encourage the development of industrial clusters in order to foster productivity gains.

In this *Economic Letter*, I describe recent research (Furman et al. 2004) that attempts to identify and quantify spillovers in a single industry: pharmaceuticals. Large pharmaceutical companies may locate R&D labs in a variety of ways. Many have several drug discovery labs, generally located on at least two continents. Others, such as Eli Lilly, which conducts most of its research in Indianapolis, have R&D facilities far from most other pharmaceutical R&D labs and near few major research universities. Yet others, such as Glaxo, which has a lab in Research Triangle Park, locate R&D facilities close to several large academic institutions as well as a number of other drug labs. Therefore, this study explores both the effects of locating R&D facilities geographically near other such facilities as well as whether spillovers emanating from "public" sources, such as academic and government institutions, differ from those emanating from "private" sources, such as other firms in the same industry.

What are "knowledge spillovers"?

Economists use the term "knowledge spillover" to describe the uncompensated (and perhaps involuntary) transfer of ideas or information from one inventor to another which can enhance the productivity of R&D efforts. This is also referred to as a knowledge or technological externality. It has long been thought that the transfer of knowledge becomes more costly with distance; that is, it may be easier to learn from someone in the same country than from someone on the other side of the world, and it may be easier to learn from a next-door neighbor than from someone hundreds of miles away. If so, then knowledge spillovers should have a geographic component.

In exploring whether geographic proximity matters, one must develop a measure of productivity for R&D. In general terms, productivity is defined as the quantity of output divided by the quantity of input. To determine R&D productivity at the level of an industry, firm, or business unit, we need to identify a reasonable measure of R&D outputs. A common measure in many settings is the count of patents generated.

In pharmaceuticals, patents are a particularly good measure due to the strong intellectual property protection they provide, especially compared to other industries. Furman et al. (2004) use the number of patents granted to a firm in at least two of the three major global markets, the United States, the European Union, and Japan. While only a low percentage of patented compounds discovered prove to be safe and effective treatments that are brought to market, the number of patents is still highly correlated with the number of products ultimately developed.

Pharmaceutical R&D

Furman et al. (2004) focus on the productivity of R&D in nine large pharmaceutical companies from 1981–1990 using detailed data on each firm's expenditures on drug discovery in various therapeutic areas, such as cancer or cardiovascular disease. With these data, one can isolate differences in output due to knowledge spillovers from those due to increased

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effort or spending, as well as from those that result from focusing on different therapeutic areas.

Of course, this industry has undergone large changes since 1990, including consolidation among many of the largest pharmaceutical companies and significant growth in the number of biotechnology companies. But, by examining the period before the growth of the internet, we can gain some key insights. A potential benefit of the internet and other advances in information technology is that knowledge may now be shared almost instantaneously and at very low cost. To assess the relevance of this potential benefit, it is important to understand whether knowledge spillovers have historically been localized, or limited by geography.

It is also important to distinguish among the sources of spillovers—that is, spillovers from R&D facilities at pharmaceutical firms and those from public research institutions, such as universities, medical centers, and government laboratories. Both types of research units have much in common. Drug discovery is highly dependent on understanding "basic" science, or the underlying biological or chemical mechanisms that drive diseases and treatments, so pharmaceutical companies employ people with advanced degrees in biology, chemistry, and related fields to conduct basic research. Like scientists and scholars at public institutions, these researchers in the private sector often publish their work in scientific journals and monitor advances made by other researchers in their fields.

However, public and private research units differ in the incentives they face in generating knowledge spillovers. Universities and other public entities (like medical centers and government labs) are not generally seeking to secure the full value of the knowledge they create, and are likely to encourage the dissemination of their work. The reason is that university researchers in general are "rewarded" for publishing their work in professional journals and for the influence that work has on the course of research in specific areas. (Note, however, that incentives for researchers in these scientific fields at public institutions have been changing in recent years, and many now patent their ideas in addition to publishing them (Murray and Stern 2004)). In contrast, a private firm has a greater need to appropriate the knowledge it generates through R&D, because it uses that knowledge to develop products it will sell. Therefore, a private firm is less likely to reveal valuable information from its R&D efforts to competing firms. The amount of research conducted in a locality is quantified by the number of scientific publications authored by individuals living in the area; this measure is also broken down by therapeutic area.

Do spillovers matter for productivity? Are they truly local?

The answer to both questions is "yes." At least as measured by patent counts, pharmaceutical firms benefit from science generated around the world as well as locally. The local effect, though, is nearly twice as strong. That is, firms around the world are better off when researchers in the London area publish more articles related to cardiovascular disease, but the firms with drug discovery labs in the London area realize the most gains.

There is an important qualification to note, however. While "public" science does appear to generate knowledge spillovers that result in more patents granted to a firm, "private" science does not. The effect of public science is quite important. On average, exposure to an additional 1000 scientific papers authored in a locality by individuals at public institutions has about the same effect on a firm's patent count as an additional $1 million of R&D expenditures. This finding suggests that firms with R&D facilities in areas with a high concentration of research facilities, such as the greater Boston area and the San Francisco Bay Area, realize a substantial boost to their productivity from local knowledge spillovers.

In contrast, proximity to the labs of competing drug firms that are publishing many scientific papers does not provide a similar boost to productivity—in fact, the measured effect is negative. There are at least two possible explanations. One is that publications by a competitor signal that the competitor has the lead in a technology race. Realizing it is behind, a firm may cut back on its patenting efforts and reallocate its drug discovery expenditures from patenting to other functions. An alternative theory is that spillovers do not simply fall from the sky: they are a result of collaboration between researchers at different institutions. It may be that a competitor can lock up scarce coauthoring resources at local universities, preventing other firms from benefiting as much from these spillovers.

Together, these findings suggest that knowledge spillovers are substantial, at least in the pharmaceutical industry, but a nuanced examination is important. If what really matters is knowledge generated by public sources such as universities rather than by other local firms in the same industry, then public funds may be more usefully devoted to development of area academic institutions rather than to the development of industrial parks or clusters (at least if increased productivity is the aim of public spending). Other researchers (Zucker et al. 1998) have noted that growth in biotechnology firms is largely related to the presence of "star" scientists at universities.

Looking beyond pharmaceuticals and ahead in time

It is interesting to speculate whether these effects have changed in the years since the data analyzed here, and whether these results apply to other sectors. Outside of changes to the structure of the pharmaceutical industry, there have been two forces at work that could affect how important localized spillovers are and how important public research institutions are. First, the advent of the internet has greatly reduced the cost of accessing scientific work performed far away. Search engines and electronic publication of articles may have mitigated the effects of distance, so that if this analysis were repeated in the period after 1995, it might reveal that the relative importance of local spillovers has diminished. Second, universities are devoting more resources to technology transfer, explicitly fostering spillovers from academics to the private sector. If their efforts are successful, then the relative importance of exposure to public science may have increased. It does appear that pharmaceutical firms have recently been relocating to areas around major research universities and medical centers.

In terms of similarities to other industries, there is some evidence that other sectors of the economy also benefit from localized knowledge spillovers, particularly from academic sources. Jaffe (1989) found that university research has a positive effect on the productivity of local firms across industries, and Branstetter (2003) finds that in California, industrial patents have been increasingly citing academic science in recent years. Some firms, such as Intel, have chosen to fund university research and foster ties with academics rather than having their own central research laboratories. If other R&D-intensive industries are similar to pharmaceuticals in the importance of the local academic institutions, it would not be surprising to see the highest growth rates in innovative activity around major research universities.

In addition, if geographic knowledge spillovers are important, then assessments of the impact of outsourcing should include considerations about how relocation affects not only employment but also the productivity of nearby organizations. In pharmaceuticals, most relocation has recently been *into* the U.S., not out of the country. This movement provides jobs and also, perhaps, a boost for the R&D efforts of surrounding firms. Correspondingly, if firms relocated their R&D labs to countries outside the U.S. because of restrictions on research or a shortage of U.S. scientists, then the U.S. would lose jobs as well as these knowledge spillovers, making the remaining firms less productive.

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