Exploring the Economics of Biotechnology: An Overview

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The recent rapid pace of discovery in life sciences raises a host of economic issues. Advances in biotechnology will likely affect the well-being of people worldwide for years to come. While we can only speculate on the specific form those advances will take, we can address many of the economic questions raised by developments in the life sciences. What potential economic benefits does biotechnology offer? How is the industry's emergence similar to the infancy of now-established industries? What legal and regulatory issues does the industry face? How will biotechnology research be financed and what are the funding hurdles? Where do biotechnology firms locate?

To address these and other important questions on the subject, the Federal Reserve Bank of Dallas hosted "Science & Cents: Exploring the Economics of Biotechnology" on April 19, 2002. The conference brought together distinguished experts who discussed economic and scientific issues related to biotechnology.

AN ECONOMIC PERSPECTIVE ON THE BIOTECH REVOLUTION

Professor **Michael Darby** of the University of California at Los Angeles opened the conference with an economic perspective on whether biotech advances will kindle a new industrial revolution. He emphasized that biotech research appears to be a major, metamorphic revolution that is creating new industries, rather than incremental progress that perfects existing products.

As with earlier metamorphic revolutions, a lack of data and history hampers our ability to gauge biotech's importance. Another characteristic of such revolutions is that many new firms enter an emerging industry that has few or no incumbents, but just a fraction of these new firms succeed and thrive. The biotech sector is still in its formative stage, so the number of firms will proba-

bly expand before declining during the shakeout phase that often occurs in an industry's development. Nevertheless, as Darby stressed, many of the economic benefits to society accrue during the consolidation and maturation stages of an industry's life cycle.

Darby also noted that biotech research is hard to imitate and has a natural excludability in that innovators have a profound advantage over imitators in creating successful applications from the research. In particular, success in biotech is highly correlated with links to star scientists at universities, and these links are empirically the most important factors affecting the probability of success. For this reason, Darby stressed that drawing top scientific talent and expanding university research are critical to increasing biotech activity in areas like Texas.

Columbia University Professor **Frank Lichtenberg** reviewed some of the limited evidence on biotech's promise from studies of the economic benefits of drugs, the most established biotech-related industry. These benefits include lower overall medical costs, higher productivity, and increased longevity. Lichtenberg said that combined, these savings imply that $34 spent on prescriptions boosts output by roughly $152.

Of course, these findings are based on past experience, and there is no guarantee that future advances will pay off as handsomely. Nevertheless, the track record for new pharmaceuticals is impressive and should be considered when evaluating policy proposals that affect incentives for innovation. This caution also applies to other biotech industries, especially in light of the key role highly risky research plays in biotech advances, a point stressed by other conference speakers.

THE INTERDISCIPLINARY NATURE OF BIOTECH RESEARCH

Two conference presentations spotlighted the complex, interdisciplinary nature of biotechnology research. In his keynote address, Rice University President **Malcolm Gillis** focused on the critical roles nanotechnology and bioinformatics will likely play in biotech advances.

Gillis noted that the development of biotech will help accelerate growth in dozens of other industries, thereby fostering overall economic growth. Biotech innovations are generally the outcome of the interplay of a collection of discoveries in different fields over a long period. In particular, Gillis stressed how biotech progress is propelled by a synthesis of new technologies, not only from the biosciences but also from other sciences, such as information technology and nanotechnology.

Gillis noted that mathematical, statistical, and computer methods are indispensable to analyzing biological, biochemical, and biophysical data. For example, computational cancer research deals with an overwhelming number of possible combinations and permutations of cancer-causing mutations, a problem bioinfor-

matics is well suited to handle. Another subfield is pharmacogenomics, which combines computational sciences with biochemistry and pharmacology and offers the potential for customizing drugs to the genetic makeup of individuals and developing new insights into disease prevention.

Gillis also described the growing research in the interface between biotechnology and nanotechnology, such as developments in the design and use of nanomaterials for biomedical engineering. He sees biotech as the principal arena for an ongoing, far-reaching synthesis of science and engineering. Gillis noted that the interplay between bio-, nano-, and information technology will have a striking impact on health maintenance, diagnosis, and treatment. He also predicted that biotechnology will provide an array of products and services to fuel sharp increases in living standards.

Tom Caskey, head of Cogene BioTech Ventures Ltd., a biotechnology venture capital fund, stressed how technical innovations from several areas of science are being used in the new field of proteomics. Caskey discussed the convergence of new technologies that enable a new industrial approach to health products. He noted that many different technologies in chemistry and biology are being combined to develop new therapeutics. For example, recombinant DNA technology and genome sequencing have helped researchers understand the structure of HIV and aided work on developing HIV vaccines and treatments. More broadly, advances in recombinant DNA technology, the study of cell growth, proteomics, and bioinformatics contribute to the development of proteins that can be used to prevent and treat diseases.

Caskey also briefly discussed the financial drivers of the biotech industry, pointing out that the National Institutes of Health (NIH) and large pharmaceutical firms are the main source of funds, with a small amount coming from venture capital. He then spoke of some developments in Texas and shared his ideas about what is needed to foster biotech in the state. These include increasing the number of new firms, improving the recruitment of pharmaceutical and large biotech firms to the region, and enabling in-state and out-of-state firms to consolidate. Caskey concluded that achieving these goals requires upgrading business plans and management, recruiting biotech talent, bolstering venture capital funding, and improving state and regional incentives.

LEGAL AND REGULATORY ISSUES FACING BIOTECHNOLOGY

Two speakers addressed the legal and regulatory issues surrounding biotechnology. Duke University Professor **Henry Grabowski** emphasized that two of the biggest hurdles for drug research are high risk and high costs. Only 22 percent of drugs that enter clinical trials eventually receive Food and Drug Administration approval, he noted. Furthermore, even among approved drugs there are few winners. Plus, R&D costs are high and are rising sharply. Adjust-

ing out-of-pocket costs for risk and time, Grabowski and his research colleagues estimate that developing a new drug costs roughly $800 million.

Obviously, inventors need to capture enough of the economic returns to make their investment worthwhile. In general, biotech firms defend their intellectual property through patents and an evolving set of legal strategies. Because R&D costs and risks are high, patents need to last long enough for firms to recoup their risk-adjusted R&D costs without unduly dissuading patent holders or their potential competitors from conducting more research. Grabowski pointed out that patents provide outsiders with information about new discoveries, which, in turn, spurs more research. He said that surveys of biotech firms have shown that considerations surrounding patent protection are the most important factor affecting R&D decisions.

Professor **Rebecca Eisenberg** of the University of Michigan also stressed the importance of patent strategies for inventors to capture the returns to R&D in biotech. An impediment to this is that existing patent practices may be unsuitable for the fast-changing biotech landscape because it takes time for the law to catch up with science. Today, the value of an innovation is not in the direct production of therapeutic or diagnostic products but in the use of that innovation in research and product development. For this reason, many innovators pursue reach-through strategies to claim a share of the value of future products. These strategies include licensing agreements that allow others to use an invention in exchange for a share of future products and pursuing damages for the unlicensed use of an invention that has led to the development of a profitable product.

Eisenberg argued that these reach-through strategies help with the valuation and financing of biotech research and tools. After discussing the pros and cons of the different strategies, she concluded by observing that patent law has traditionally limited patent protection to actual accomplishments and future variations that arise from work that is routine and predictable. She considers this a sensible limitation that guides patent examiners away from granting patent rights that would unreasonably cover future research. Eisenberg believes there are good reasons for permitting prior innovators to capture a fair share of the value their discoveries contribute to subsequent downstream innovation. Nevertheless, she is generally more comfortable with strategies in which licenses are negotiated in the marketplace than with strategies that require negotiation in the course of patent prosecution.

FINANCING BIOTECH RESEARCH

Funding expensive research that has highly risky returns is another hurdle for biotech. Aside from pharmaceutical research, which is often done by established companies, much biotech research is conducted by new firms that are partly funded by venture capitalists and other private equity investors. Much of

their applied research is based on basic or generic research that is either publicly funded or conducted at publicly funded universities and other institutions. Given that future biotech research is likely to branch out beyond old-style pharmaceutical R&D, the session on funding biotech research focused on the roles played by venture capital and the public sector.

Timothy Howe, a founding partner of the venture capital firm Collinson, Howe & Lennox, emphasized several points about the role of venture capitalists. First, biotech venture capital firms combine managerial with scientific talent in picking, funding, advising, and even managing biotech start-ups. This enables scientists at start-up firms to focus on inventing. A second point is that most venture firms directly invest in young companies, without intermediaries. The distribution of returns is highly skewed, with few big winners. Venture capital firms also have an incentive to diversify their investments across different solutions to medical problems, which can be found not only in biotechnology but also in medical devices and health service firms.

Howe sees a shift in the type of science funded by venture firms, from conventional drug development in the 1980s and genomics in the 1990s to projects in proteomics, the study of how human genes produce proteins that act on the body. Howe sees the pharmaceutical industry moving from being vertically integrated to horizontally organized and dominated by a few major players in distinct horizontal segments, such as research and target discovery, clinical testing, and distribution. Finally, Howe believes the rising share of gross domestic product devoted to health and the related aging of the baby-boom generation are big incentives for venture capital firms to enter the medical arena.

Another important source of funding for biotech research is government. Wake Forest University Professor **Michael Lawlor** emphasized that the benefits arising from certain types of research warrant some form of public subsidy. Lawlor asks why returns to R&D have historically exceeded those on other investments and have not been driven down to normal by increased investment. One reason is that there are high-risk premiums on biotechnology investments because there are few winners. Another is that the economic value generated by inventors' discoveries spills over to others, and inventors recoup only a part of the economic value of their research.

Lawlor discussed three public policy options for addressing underinvestment, along with the drawbacks of each: an industrial policy (which invests directly in the research and production of goods), tax incentives, and direct funding of R&D. Because of the drawbacks to the industrial policy and tax approaches, the United States has mainly pursued a strategy of directly funding basic research through the National Institutes of Health, coupled with developing a system of patent and copyright protections for applied research. From Lawlor's perspective, NIH's approach yields many public benefits, while limiting some of the pitfalls of government intervention. In particular, he noted that Congress sets the

overall budget of the NIH, but panels of scientists select the research projects to fund.

Lawlor stressed that in recent decades public R&D funding has changed in response to the increased complexity of research, which is more interdisciplinary and has blurred the lines between basic and applied research. Recognizing this and seeking to encourage the transfer of federally funded research to the private sector, Congress passed legislation in the mid-1980s creating cooperative research agreements that allow federally funded laboratories to establish profitable links with commercial firms. Lawlor noted that the complex, direct-funding approach that has evolved in this country has helped make the United States the world leader in biotech research.

LOCAL DETERMINANTS OF BIOTECH RESEARCH

Dennis Stone, vice president for technology development at the University of Texas Southwestern Medical Center in Dallas (UTSW), focused on biotech activity in the Dallas/Fort Worth metro area and emphasized the role of the university. Unlike the information technology industries, biotech depends on the university as a technology source. Stone illustrated the scope of the University of Texas' biotech presence, using life science research expenditures and patent data.

Stone noted that Dallas has few biotech companies because of barriers to entry facing start-ups. In his opinion, the main barriers include the lack of biotech entrepreneurs, the lack of local venture capitalists, the academic culture of local faculty, and the fact that UTSW cannot form companies. Stone said that fostering the growth of seed capital, venture capital, and biotech space is needed for biotech to flourish in Dallas. In addition, he sees a need to increase the flexibility of firms to operate with public institutions such as UTSW and to bolster cooperation among North Dallas stakeholders.*

The last conference speaker, UCLA Professor **Lynne Zucker**, discussed broader patterns across the country. Zucker began with a glimpse of Texas' science base. Using several gauges, she showed that Texas was below the high-tech-state average for a variety of measures of scientific prowess.

Zucker stressed that biotech has had few big winners and many losers, as only 10 percent of biotech start-ups grow into reasonably large firms. Her research shows that basic university science is integral to successful commercialization of scientific discoveries. Firms working with star scientists are much more likely to be successful, controlling for other factors. Her findings also show that local venture capital has been key to the industry's growth, increasing the productivity of R&D and fueling firms' expansion. Zucker concluded by noting that Texas' biotech success will be driven by the number and quality of

* Dr. Stone's presentation is not included in this proceedings.

top research university bioscientists, especially those with ties to firms, and stressed the need for more investment in the state's scientific base.

ECONOMIC IMPLICATIONS OF BIOTECHNOLOGY

Several broad implications arise from the conference. One is that if past technological revolutions are any guide, more research is needed to develop gauges of biotech activity. Also, the benefits of biotech advances are likely to be felt long after the inevitable shakeouts that will cull firms' ranks. In addition, although health care premiums are growing rapidly and drug cost increases are getting a lot of press, we should remember that the benefits of new drugs have historically outweighed their higher cost.

Another broad implication is that while policymakers should spur basic and generic research, they must ensure that incentives are appropriate for markets to perform efficiently. Intervention in the form of price controls or forcing biotech firms to relinquish property rights could discourage innovation. Given the high cost and risks of biotech research, emerging industries need a few big winners to justify investing in many new ideas. In addition, patent and royalty laws need to catch up with technological innovations so markets can perform better.

Other implications concern the interdisciplinary nature of biotech research, which encompasses a broad scientific base and may greatly affect other areas and industries. Current biotech science draws on advances in chemistry, biology, computational methods, and medicine to develop new therapeutics. Looking ahead, the interplay of advances in biotechnology, informatics, and nanotechnology could extend biotech applications to an array of products and services inconceivable only a short time ago, greatly improving quality of life and boosting economic growth. But to succeed, biotechnology firms must draw on specialists from different areas, foster technical collaboration among these scientists, and credibly communicate their findings to regulatory agencies, customers, and investors.

The conference presentations also have implications for investors. Direct implications include recognizing the high risks in holding large stakes in individual biotech firms. Given the difficulties in capturing the value of inventions, investors should consider the risk that innovations could benefit end users more than inventors.

Perhaps the biggest implications for investors arise from the indirect effects of biotech research on benefit costs and customer bases for all sorts of companies. In particular, biotech could increase longevity beyond most projections, raising the risk to firms with large defined-benefit pension obligations and the Social Security retirement system. On the other hand, medical advances might help control the projected jump in Medicare benefits, which are expected to produce bigger budget shortfalls than the looming Social Security problem. Another demographic implication is that spending patterns could shift more

than expected if longevity increases more rapidly than projected, particularly if medical advances reduce disabilities and improve the quality—as well as the quantity—of life.

The conference presentations also have implications for local government policies aimed at fostering biotech activity. The recipe for success in biotech seems to be a strong scientific base built around top-rated academic institutions, which provide groundbreaking research and draw star scientists to the region. The second important element is the ability to commercially develop the innovations coming out of research institutions. To become a major player in the biotech arena, Texas needs to not only continue to develop its strong research base but also foster the venture capital investment needed to commercialize the innovations from the state's research institutions.