Southwest Economy

The Euro Cash Changeover

At midnight on Dec. 31, 2001, for the first time in history, a currency that had not been debased through inflation had its legal tender status revoked. From its introduction in 1948, the German mark was one of the world's strongest currencies and was viewed as one of the great achievements of the postwar Bonn Republic. Its replacement by the euro signifies a major milestone in European integration. On Jan. 27, the mark was joined by the Dutch guilder, and on Feb. 9 the Irish punt disappeared into history. The French franc became a thing of the past on Feb. 17, and at midnight on Feb. 28 all of the legacy currencies of the 12-nation euro area ceased to be legal tender. The euro is now the only legal tender in most of Western Europe.

The introduction of euro banknotes and coins, which began on Jan. 1 of this year, was a great success. The predictions of long lines at retail outlets and railway stations were not borne out, and the European public has embraced the new currency with an enthusiasm that surprised even its most ardent supporters. There were glitches, but they were few. The cash changeover, far from marking the beginning of the end of economic and monetary union (EMU) as some had expected, simply marks the end of the beginning.

(Continued on page 2)

The Economic Impact of Biotechnology

It's as daunting a task today to divine how biotechnology will affect future economic activity as it might have been for economists in the 18th, 19th and 20th centuries to forecast how the steam engine, electricity and the microchip would influence and eventually transform the world economy. With the assistance of mind-boggling inventions, humankind's bucolic existence has morphed into a world that our agrarian ancestors would scarcely recognize. Biotechnology may change our world as much.[1]

Even though the bioscience industry has been around for 25 years and the gargantuan task of mapping the human genome is complete, it's still not clear to what extent life science technology will affect our economy. Some observers have already labeled this the "Biological Century," betting that advances in the life sciences will yield changes more momentous than those of electricity and computers. Such predictions may be overinflated, but bio-

(Continued on page 6)

The Economic Impact of Biotechnology

(Continued from front page)

technology has the potential to greatly affect the economy.

Two types of economic effects are already appearing in the nascent industry. By analogy, they resemble the *direct* splash of a stone tossed into a still pond and the *indirect* rippling that follows. Direct impacts from biotechnology include such obvious pluses as research and development (R&D) spending, sophisticated jobs and tax revenues. Biotech companies have already sprouted up in many parts of the country (*Chart 1*). Less visible are the indirect effects, which include improvements in quality of life and living standards stemming from faster labor productivity growth, better health products and services, and a cleaner environment.

Landmark discoveries and novel inventions have marked biotechnology's early history. These advances, propelled by public funding and market incentives, have increased interest and sustained research activity. The current marketplace is characterized by intense competition but also by cooperation among public and private stakeholders. However the industry and supporting science play out, the advent of biotechnology could profoundly affect our lives.

What Transforms Market Economies?

Historically, the combination of groundbreaking discoveries and subsequent commercialization has preceded periods of prolonged economic expansion. For example, the Industrial Revolution in Great Britain was launched by a confluence of new technologies with commercial potential, such as the steam engine. Later, the internal combustion engine and electric power revolutionized America. More recently, William Shockley's transistor and Jack Kilby's microchip laid the foundation for the Information Age. All these eras of discovery and applied research were followed by strong economic growth.

Benchmark discoveries and innovations such as steam power, electricity and the microchip always garner the most attention. But it's usually not until the technology is harnessed and products are mass produced that we see economic consequences.

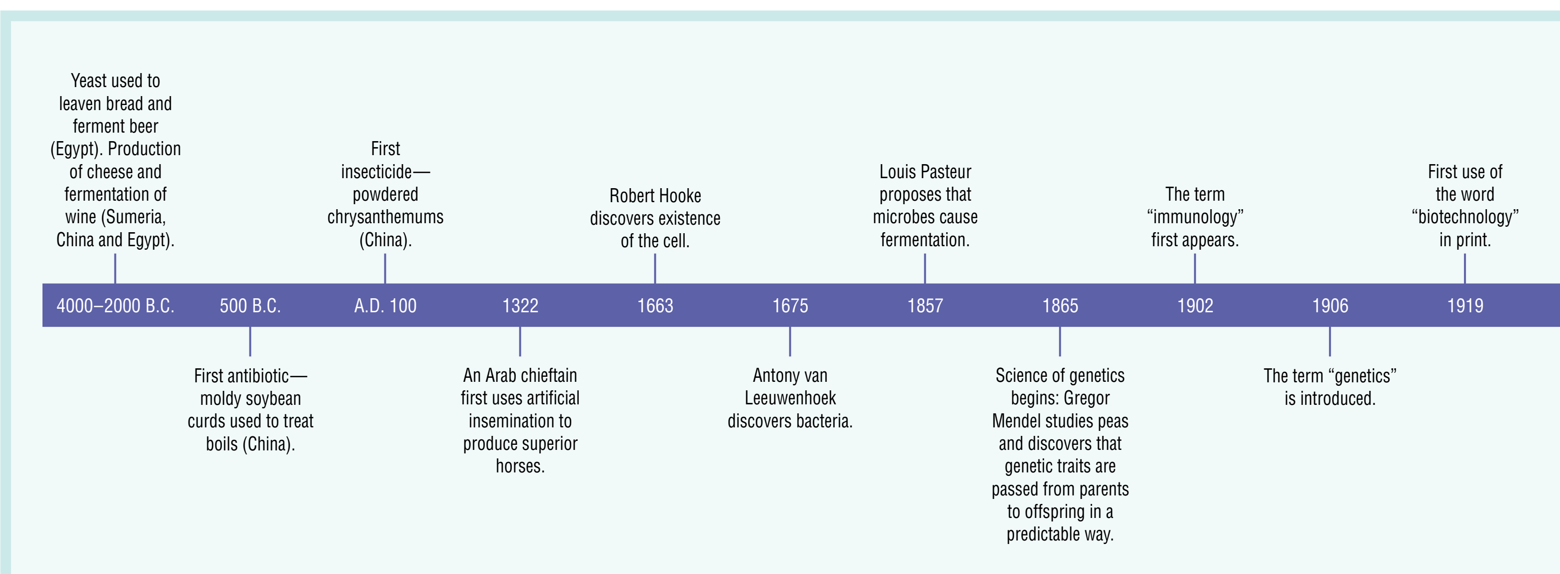
Similarly for biotechnology, completion of the human genome map—while transcendent in scientific importance—will remain of little use commercially until the information can be used to combat human disease. Scientists are making significant headway, but as recently as 2001, one report said the genome sequencing has not yet "materially affect[ed] the speed of development of any given product."[2] All this is not to understate the gains in biotechnology in recent years but to point out that it will take time before products are conceived and economies materially affected.

The Splash (Direct Impact)

Karl Ereky, a Hungarian engineer, first coined the word biotechnology in 1919. At the time, the term referred to all lines of work involved in creating products from raw materials with the aid of living organisms. Today, the Biotechnology Industry Organization (BIO) defines biotechnology as "the use of cellular and molecular processes to solve problems or make products."

In May 2000, BIO commissioned Ernst & Young to determine the aggregate impact firms involved in biotechnology have on the U.S. economy. The study looked at information from firms whose primary business operations fell under five Standard Industrial Classification codes. While some components of biotech activity are not included in this definition, the report gives an idea of the direct impact bioscience is having on the economy.[3]

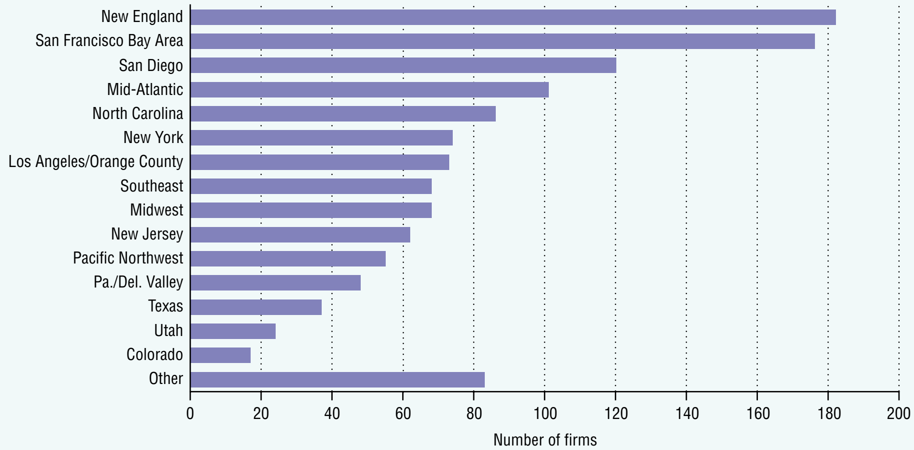
The study reveals impressive growth for the industry. The life science industry



Biotechnology Timeline

Chart 1

Private and Public Biotech Companies by Region



SOURCE: Ernst & Young, *Biotechnology Industry Report: Convergence, 2000.*

more than doubled revenue from $8 billion in 1993 to $20.2 billion in 1999. R&D spending was $11 billion in 1999, not counting monies spent by colleges, universities and nonprofits. Total tax collections reached nearly $10 billion. Federal taxes accounted for $6.8 billion of the total and state and local taxes for the remainder.

Completion of the human genome and promises of new medicines sent biotech share prices skyward in 1999 and 2000. Since then, sparse profits and the realization that investment returns to biotechnology are going to take some time have kept overall stock prices subdued (*Chart 2*). Profitability in the four largest biotech firms has instilled recent confidence in the sector, but the majority of firms have yet to show a profit.

Biotech activity should continue to expand. Overall health care and prescription drug expenditures have increased steadily in recent years. For example, health care expenditures as a percentage of GDP have grown from 8.8 percent in 1980 to 13 percent in 2000. Prescription drug expenditures have been climbing steadily since 1994 (*Chart 3*). The aging of baby boomers will only augment such trends. Recognizing the growth potential in the industry, 41 states, including Texas, New Mexico and Louisiana, are currently pursuing economic initiatives to foster growth in their emerging biotechnology sectors. (See the box titled “BioTexas.”)

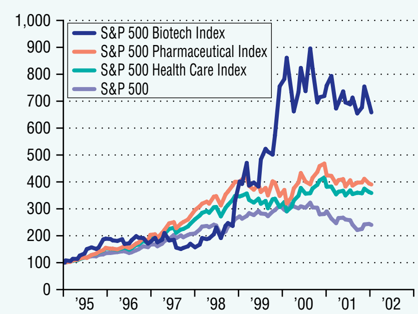
The Ripples (Indirect Impact)

Still a relative newcomer to the economy, biotechnology is already having a positive indirect influence on economic activity. Ernst & Young estimates that biotechnology has an employment multiplier of 2.9. In other words, each job

Chart 2

Health Care Indexes, 1995–2002

Index, January 1995 = 100



SOURCE: Bloomberg.

1928 — Alexander Fleming discovers penicillin as an antibiotic.

1933 — Hybrid corn is commercialized. By 1945, hybrid corn, with its remarkable yields, accounts for 78 percent of U.S.-grown corn.

1944 — Oswald T. Avery and his colleagues at the Rockefeller Institute in New York discover that deoxyribonucleic acid (DNA) is the substance that carries the genetic information.

1953 — In Cambridge, 24-year-old scholarship holder James Watson and 36-year-old physicist Francis Crick describe the double-helix structure of DNA.

1955 — Frederick Sanger decodes the amino acid sequence of insulin and thus shows for the first time that proteins consist of a defined sequence of amino acids.

1966 — The genetic code is cracked, demonstrating that a sequence of three nucleotide bases determines each of 20 amino acids.

1973 — Herbert Boyer and Stanley Cohen succeed in recombining DNA for the first time. This experiment is regarded as the birth of genetic engineering.

1976 — Genentech, the first biotechnology company, is founded by Robert Swanson and Herbert Boyer.

1990 — The Human Genome Project—an international effort to map all the genes in the human body—is launched.

2001 — Scientific journals publish the complete human genome sequence.

SOURCES: Biotechnology Industry Organization; Schering AG, Germany; Genentech Inc.

BioTexas

The Texas life science industry is still in a fledgling stage. In recent years, the industry has garnered considerable interest among investors, politicians, consultants and community developers but remained relatively small. The Texas Healthcare and Bioscience Institute (THBI) reported that the Texas life science industry employed 50,650 people in 1999, only 0.5 percent of statewide employment. Life science jobs in the state have continued to grow, however, increasing at an annualized rate of 1.4 percent between 1997 and 1999.[1]

Dallas, Houston, Austin and San Antonio are the life science strongholds, making up two-thirds of the total industry employment. Even though it is small, the industry is already having a positive effect on local economies. Compensation for those working in the industry is relatively high; life science employees earn an average of $48,623, considerably higher than the state average of $34,936.

Growth in the life science industry is unequivocally tied to the rate of intellectual property generation and commercialization. Life science intellectual property in Texas is growing quickly but still lags the powerhouses of California, New York, Massachusetts, New Jersey and Pennsylvania. THBI reports that life science patents issued to Texas residents increased 54 percent from 1997 to 1999, reaching a record 577 in 1999. Novel intellectual property will continue to increase as individuals are trained in the life sciences. State institutions of higher learning awarded 17,894 life science degrees in 1997.

Grants, endowments and investments enable researchers to discover new life science technologies and bring them to market. Texas ranked third nationwide in 1999 in university dollars earmarked for life science research and development. In all, just over $1 billion was spent, an 18.1 percent increase over 1995. Most of the funding went to Baylor College of Medicine, Texas A&M University and University of Texas Southwestern Medical Center at Dallas.[2]

Texas researchers are beginning to bring biotechnology-related ideas to market. According to THBI, income from Texas intellectual property increased from $4.2 million to $25.6 million between 1993 and 1999. Although still small, it represents more than a 500 percent increase. Such returns reinforce the incentive to produce biotech research that can be commercialized.

The state government is committing vast resources to the Texas biotechnology cause. The 2001 Legislature appropriated $800 million for science, engineering, research and commercialization activities. Various research parks that include facilities for life science companies will benefit from the Legislature's commitment. These facilities include BioHouston, the Texas Research Park in San Antonio, the Woodlands Research Forest and the Harrington Regional Medical Center in Amarillo.

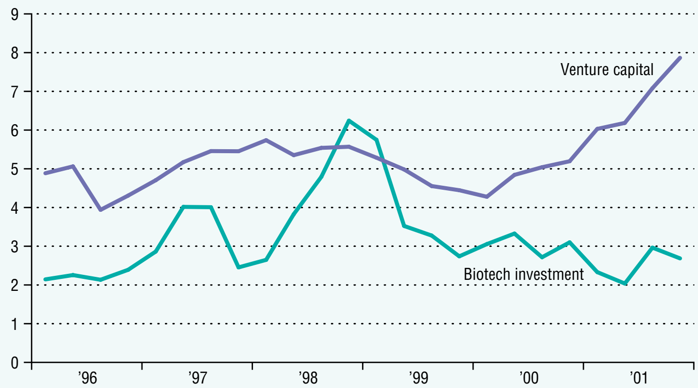
Chart B1

Texas Venture Capital Financing Moves with Overall U.S. Venture Investment

SOURCES: PriceWaterhouseCoopers MoneyTree/Venture One surveys through 2001:3; authors' calculations.

Chart B2

Texas Share of Total U.S. Venture Capital Investment Rises, While Biotech Investment Share Remains Low



NOTES: Four-quarter moving averages. Biotech includes biopharmaceuticals, medical devices and medical information systems.

SOURCES: PriceWaterhouseCoopers MoneyTree/Venture One surveys through 2001:3; authors' calculations.

Within the biotech sector and across all industries, the pace of venture capital investment in Texas is dominated by national fluctuations related to changing conditions in U.S. financial markets. Last year, venture capital investment in Texas fell sharply, in line with the national decline (*Chart B1*), much of which paralleled the fall in the Nasdaq stock index.[3]

Abstracting from these general movements, Texas' share of U.S. biotech venture investment has varied within a low range of 2 to 3 percent in recent years, even though Texas' share of overall venture capital investment has risen to about 7 percent, roughly the state's share of the U.S. population. This disparity, depicted in Chart B2, reflects that venture capital investment in other high-tech industries and in non-health care services in Texas has outstripped growth elsewhere in the United States, while Texas' venture investments in health care and biotech have lagged the national pace.[4]

These differences likely stem from factors affecting the state's regional comparative advantage across industries. Nevertheless, like the vast majority of states, Texas' shares of U.S. venture capital investment across industries is also held down by the disproportionately high concentration of venture investment in California (44 percent of the U.S. total in 2001:4) and, to a lesser extent, in New England and New York.

Texas life science firms could flourish if three key challenges are surmounted. First, strong local scientific and academic norms must permit the rapid translation of academic results into competitive enterprises. Second, researchers and stakeholders need good access to capital. And third, favorable royalty schemes between the researcher and universities must protect incentive structures for scientists wishing to take their intelligence to market.

Notes

1. *THBI 2001 Index*, Texas Healthcare and Bioscience Institute, 2001.
2. *State Government Initiatives in Biotechnology 2001*, September 2001. Report prepared for the Biotechnology Industry Organization by the Technology Partnership Practice, Battelle Memorial Institute and State Science and Technology Institute.
3. For details on venture capital, see, "The Venture Capital Revolution," by Paul Gompers and Josh Lerner, in *The Journal of Economic Perspectives*, vol. 15, Spring 2001, pp. 145–68, and "How Does the Stock Market Affect the Economy?" by John V. Duca, in Federal Reserve Bank of Dallas *Southwest Economy*, September/October 2001.
4. The charts use data from the PriceWaterhouseCoopers Money Tree/Venture One survey through 2001:3. This survey, which was revamped in 2001:4, is now called the PriceWaterhouseCoopers/Venture Economics/National Venture Capital Association MoneyTree Survey.

created in biotech generates an additional 2.9 jobs, resulting from biotech firms' purchases and consumer spending of biotech employees. With the multiplier effect, biotech's total impact on employment comes in at more than 437,000 jobs.

Ernst & Young gives biotech a 2.3 revenue multiplier, increasing the total impact on revenues from biotechnology to $46.5 billion. The personal income multiplier is estimated to be 2, which results in a $28.8 billion total impact on personal income from the industry.

Biotechnology's contributions to medicine and health care are growing rapidly, promising to increase human longevity and healthiness. To the extent that biotechnology results in new treatments for old ailments, people will become more productive over their lifetimes.

In addition, improved strains in agricultural crops have helped increase yields for many years. Research and development of more-productive and disease-resistant crops have enabled output per farmer to increase steadily. Improvements in quality of life will continue as scientists further harness biological processes to clean up hazardous waste and contaminated areas. Environmental remediation is growing fast as a result of increased public demand for a cleaner, safer and more natural living space.

Structure of the Bioscience Industry: Form Follows Function

The structure of the bioscience industry is in flux. Advances in biotech science have led to an evolution of the industrial structure: from the domination of large-scale firms to the entry of many small, innovative start-ups to alliances between the large and small for a more efficient way of doing business.

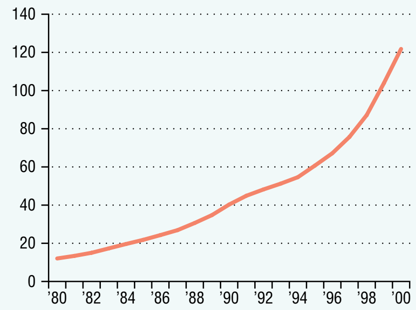
Stanley Cohen and Herbert Boyer's transfer of DNA from one organism to another in 1973 was a major milestone in biotech, leading to an explosion of new research and production mechanisms and a change in the industry's organization. This advance in genetic science propelled the industry along two different paths, according to Henderson, Orsenigo and Pisano (1999).

One path employed genetic science as a process technology, that is, using the methods of Cohen and Boyer to mass produce proteins as therapeutic agents.

Chart 3

Expenditures on Prescription Drugs

Billions of U.S. dollars



SOURCE: Health Care Financing Administration.

Genetic engineering required competency in the new techniques and a different type of R&D effort by firms. Before genetic engineering, a small number of proteins could be manufactured either from natural sources or by organic chemical methods. Genetic engineering made it possible to produce large quantities of proteins, opening a completely new area for drug research. Henderson, Orsenigo and Pisano argue that this process technology was the force behind the first large-scale entry into the biotech industry since the early post-World War II period. Zucker, Darby and Brewer (1998) also note that the number of firms using biotechnology "grew from nonexistent to over 700 in less than two decades, transforming the nature of the pharmaceutical industry."

The second path employed biotechnology techniques as a research tool for discovering and manufacturing conventional, "small molecule" drugs.[4] This trend reinforced the dominance of the large pharmaceutical firms, which were able to leverage their competency in chemical R&D processes to build off the knowledge already codified in the academic literature.

The academic research done in universities in the 1970s and 1980s spawned many small, innovation-rich start-up companies, beginning with Genentech, formed by Boyer and Robert Swanson in 1976. The 1990s brought much merger activity as large biotech companies purchased innovative start-ups.[5] Often, the mergers occurred because the target R&D firms, while rich in talent, were poor in capital and resources to commercialize products. These start-ups needed the distribution and production processes of larger firms to take their products to market. Conversely, larger firms needed new ideas but often found it more economical to acquire brain-rich start-ups than to expend scarce resources for cutting-edge in-house research. Moreover, by buying an established firm, a larger firm was able to mitigate the uncertainty inherent in R&D efforts.

Public and Private Collaboration

Much basic biotech research has been publicly funded and conducted at universities because the research is a public good and has positive spillovers. (See the box titled "Biotech: A Public Good?") The National Institutes of Health (NIH) funds the majority of biotech research in the United States. The NIH budget in 2001 was $20.5 billion, or roughly twice the size of private spending on biotech R&D in 1999 (the most current year for which we have data). About 82 percent of the NIH budget is for grants and contracts that support research and training in universities. Another 10 percent goes toward in-house research. Henderson, Orsenigo and Pisano report that NIH spending on basic research has had a significant effect on the productivity of the large firms that received funds.

Studies suggest that the public-good

Biotech: A Public Good?

Public funding through government agencies and universities has been a major factor in the history of biotech research. Such funding is an efficient way to advance biotech research, which, like all basic research, has certain public-good characteristics and positive spillover effects.

Public goods are those in which consumption is nonrival and nonexcludable or where exclusion is very costly. For example, the outcome of a biotech experiment can be considered a public good. When the experiment's outcome is published, it becomes hard to exclude people from seeing the results (nonexcludability). And, an individual knowing the results (consuming the good) does not compete with another's ability to consume (nonrival in consumption). In fact, the additional cost of another person knowing the results is nil.[1]

The nonexcludability characteristic also gives rise to what is called a free-rider problem. Consumers of the good have no incentive to pay when they know they can get the good for free. Because of the nonexcludable nature of biotech "goods," firms have no economic motivation to advance the research. For this reason, most public goods (such as basic research, national defense and so forth) are paid through taxes.

Moreover, if a good has positive spillover effects, benefits accrue to people other than those paying for the good. Private production of the good then would be less than optimal because it would not take account of the spillover benefits accruing to consumers who did not specifically buy and pay for the good.

Possibly recognizing the public-good qualities of basic biotech research, the Morrill Acts of 1862 and 1890 were passed in response to the growing demand for agricultural and technical education. The beneficiaries of the Morrill Acts were institutions designated as land-grant universities, the first publicly supported venues for biotech research. The acts provided these institutions with federal land grants and monies. A key component of the system was the Agricultural Experiment Stations, which promoted agricultural research.

The majority of public funds for biomedical research now flows through the National Institutes of Health (NIH). NIH first emerged in 1887 as the Laboratory of Hygiene in Stapleton, N.Y. This one-room lab was initially set up to find cures for infectious diseases such as cholera, typhoid fever and smallpox. In 1930 the lab was expanded, reorganized and renamed the National Institute of Health. In 1948, the lab widened its scope, and four institutes were created to support research on cardiovascular disease, mental illness, infectious diseases, and experimental biology and medicine. These days, the goal of NIH is to acquire new knowledge to help prevent, detect, diagnose and treat diseases and disability.

Because there is quite a bit of learning by doing in biotech research, Zucker, Darby and Armstrong (2001) argue, some biotech innovations are excludable. The excludability arises from the complexity or tacitness of the information necessary to practice the innovation. This information is held by a small number of star scientists and hence does not disseminate as quickly. However, the authors do suggest that publicly funded research greatly benefits the biotech industry. Public funding of biotech research can be justified insofar as it continues to display public-good qualities.

Note

1 This is in contrast to a private good, such as food, where one person's consumption leaves less for others and it is relatively cheap to prevent others from consuming it.

aspects of biotech research make it costly to work through the market and that mergers and acquisitions are one way of internalizing these costs. Gaisford et al. (2001) posit that restructuring activity can be motivated by institutional failure or weak patent protection and incomplete contracts. Disputes between biotech companies over the control of patent and contractual rights to key technologies have landed many of them in court. Vertical integration solves some of these contractual problems and helps firms protect the returns on their innovations.

Mergers and acquisitions also allow companies to take better advantage of their relative strengths. Life science firms generally have different comparative advantages in producing knowledge, whether it be codified (designs, formulas, patents), tacit (learning-by-doing) or distributed (only valuable if used in conjunction with others). Because transferring knowledge between independent firms through the market is difficult, firms vertically integrate to make such transfers more efficient.[6]

In addition to corporate restructuring has been the rise of strategic alliances among firms. Such partnering allows two or more firms to combine forces without bearing the cost of merging or coordinating a joint venture. Alliances have been important for biotech innovation because established firms find it difficult to keep abreast of all the industry's technological advances, according to Filson and Morales (2001). Their study shows that firms in a strategic alliance purchase some of their R&D partner's equity, thus gaining shareholder influence to better monitor the R&D firm and to allay some of the investment's uncertainty. Some recent examples are collaborations between Nanogen and Hitachi; Affymetrix and Perlegen; OSI Pharmaceuticals, Genentech and Roche; Bayer and CuraGen; and Abbott Laboratories and Millennium Pharmaceuticals.[7]

Zucker, Darby and Armstrong (2001) show that basic university science is integral to the successful commercialization of scientific discoveries. Star scientists provide the intellectual capital that defines the firm's core technology and largely determines the company's success. The researchers also show that collaboration between academic and corporate scientists has a significant effect on a wide range of firm performance measures. For example, for an average firm, Zucker, Darby and Armstrong (1998) find that five articles coauthored by academic stars and the firm's scientists imply about five more products in development, 3.5 products on the market and 860 more employees.

According to Zucker, Darby and Brewer (1998), the location of top scientists also predicts where new technology firms will locate. The bioscience industry's growth and location from 1975 to 1990 was dependent on the growth and location of intellectual capital. Intellectual capital flourished around the great universities (the authors cite 20), but the existence of outstanding scientists played a role over and above the presence of universities and government research funding. Local venture capital also was important to the industry's growth.

The evolution of the bioscience industry provides insights into how states, all now vying for a piece of the biotech pie, can focus their efforts. The recipe for success seems to start with strong academic institutions and laboratories with a good research base. These institutions will provide the groundbreaking research and draw top scientists to the region. Another ingredient is an institutional structure that will aid technology transfer or commercialization of innovations arising from the research and that will foster start-up companies. In the long run, firms will go where the research and start-ups are percolating.

(Continued on back page)

Economic Impact of Biotechnology

(Continued from page 10)

Conclusion

Life science as a formal industry has only been around for a quarter century, but using living organisms to advance human life quality has transpired for thousands of years. Public funding has expedited growth in the life sciences and catalyzed private interest in the sector. Like the gains from trade among countries, trading among private and public entities has been key to industry growth in recent years. In particular, universities, labs and incubators laden with ideas and brainpower have collaborated with industry leaders whose deep pockets have enabled them to produce, market and sell new life science products. While it is too early to tell what the overall impact of biotech will be, the industry's effect on the economy is already noticeable and growing fast.

—John Thompson
Mine K. Yücel
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Notes

1 The terms life science technology and biotechnology are used interchangeably in this article.
2 See Ernst & Young (2001), p. 5.
3 Standard Industrial Classification codes included in the definition are 2833, 2834, 2835, 2836 and 8731. See Ernst & Young (2000).
4 See Henderson, Orsenigo and Pisano (1999), p. 283.
5 For example, Monsanto bought Calgene and Agracetus, Dow Chemical acquired Mycogen and Dupont bought Pioneer Hi-Bred. More recently, about 12 acquisitions took place from 2000 to mid-2001.
6 See Gaisford et al. (2001), p. 178.
7 See Ernst & Young (2001), p. 58.

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