PRIVATIZATION AND INNOVATION IN AGRICULTURAL BIOTECHNOLOGY

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1. Introduction

Over the last 150 years, agriculture has been subjected to several waves of innovations, including biological and chemical innovations that increase agricultural productivity, alter its input use, and modify its structure. Agricultural biotechnology is now emerging as a wellspring of innovations that will reshape agriculture as profoundly as any previous innovation paradigm. This new technology has unique features which must be understood in order to formulate appropriate government and academic policy.

2. Privatization of Knowledge Associated with Biotechnology

Biotechnology utilizes the tools of modern molecular and cell biology, including gene splicing, and has been most widely applied to medical purposes, both therapeutics and diagnostics. Agricultural applications lagged somewhat, but share many of the characteristics that have shaped the evolution of medical biotechnology. All developed directly from basic scientific research, with the generic technology transferred from universities to the private sector for development and marketing. Long product development time, uncertainty, and large downstream investments make intellectual property protection important and foster a business model based on technology licenses to start-ups that are later acquired by major corporations. In 1994, 17 of 45 universities had earnings from their patenting (AUTM, 1995); in 1999, 25 of 45 surveyed U. S. universities reported earnings from their patents (Parker, Castillo, and Zilberman, 2001). Our paper will overview some of the features of technology transfer from the university to the private sector, and it will analyze some of its implications.

3. The Bayh-Dole Act and the Proliferation of Offices of Technology Transfer

The Bayh-Dole Act, passed in 1980, gave universities ownership of discoveries resulting from federally funded research, which formerly were put in the public domain.

Universities established Offices of Technology Transfer (OTTs) to identify patentable inventions and license the rights to private companies. A major justification for the Bayh-Dole Act was that private companies had insufficient incentive to invest in university innovations because they could not establish adequate intellectual property protection. Following enactment, universities increased their patenting and licensing activities (Mowery, 2000). Universities have seen increased utilization of academic inventions and received significant licensing royalties, amounting to almost $600 million in 1999 (Parker, Castillo, and Zilberman, 2001). Table 1 provides a list of the major income-earning innovations that were sold by the University of California. Much of the benefits were captured by a small number of big hits.

Although biomedical inventions generate the highest royalties, agricultural licenses generate roughly 10 percent of the revenues to public universities. Strawberry varieties, for example, generate $2 million annually for the University of California and Gatorade, a food product invented at the University of Florida, has generated royalties of more than $60 million since it was licensed in 1967 to a major manufacturer (Newbart, 2000). Veterinary innovations include vaccines, diagnostics, and products that enhance livestock productivity. While some are concerned that the increasing licensing activity by universities may result in academic research agendas driven by the industry (Kenney, 1986), it has been widely recognized that basic scientific research at academic and non-profit institutions has been the most efficient way to create the breakthrough knowledge required to develop commercial applications of biotechnology (Parker and Zilberman, 1993).

4. Start-Ups and Takeovers

While the Bayh-Dole Act addressed some legal impediments to commercialization of inventions by academic scientists, the high uncertainty associated with new technology and the resistance of corporate R&D departments to going outside for new knowledge limited major corporations' interest in investing in promising academic innovations. In

TABLE 1

University of California

TOP EARNING COMMERCIALIZED INVENTIONS

Fiscal Year 1999

Invention	Campus	Year Disclosed	Revenues ('000)
Hepatitis-B Vaccine	SF	1979 &1981	$28,997
Process for Gene Splicing	SF	1974	14,618
Human Growth Hormone	SF	1977	5,420
Intracranial Aneurysms Treatment	LA	1989	4,069
Nicotine Patch	LA	1984	2,209
Camarosa Strawberry	DA	1992	1,955
Liposome Sizing Method	SF	1977	1,323
Interstitial Cystitis Therapy	SD	1980	1,296
Fluorescent Conjugate Probes	BK	1981	1,124
Yeast Expression Vector	SF	1982	1,119
Liposome Storage Method	DA	1984	837
Radiographic Media	SD	1979	797
Feline Leukemia Virus Diagnostic	DA	1980	741
Cochlear Implants	SF	1979	588
Aids for Learning Disabled	SF	1994	515
Magnetic Resonance Imaging	SF	1976	509
Feline AIDS Virus Diagnostic	DA	1986	562
Fluorescence Gel Scanner	BK	1990	412
Metabolizable Chelates	DA	1987	355
Phosphorus Plant Fertilizer	RV	1990	268
Intracellular DNA/RNA Targeting	SF	1991	260
Atomic Force Microscope	SB	1989	256
Fluorescence Scanner	BK	1992	247
Chandler Strawberry	DA	1982	244
Selva Strawberry	DA	1999	233

Total Income (Top 25 Inventions)	**$68,954,000**
Total Income (All Inventions)	**$80,889,000**

Source: University of California Technology Transfer Office Annual Report FY1999. Accessed on line at: http://www.ucop.edu/ott/annual99.pdf

many instances, university technology transfer efforts have thus focused on start-up businesses. They match up university scientists and venture capitalists and help to form new companies. Many major biotechnology companies in the Untied States started this way, including Genentech, Amgen, and Chiron. Universities have reportedly spawned close to 4,000 new companies over the last 20 years, including agricultural companies such as Calgene and DNA Plant Technologies. Once the technology is developed sufficiently to demonstrate viability, major corporations invest, often by acquiring the start-ups. Monsanto, for example, acquired Calgene, which owned the patent for the agro-bacterium transformation technique.

5. The Gains from Privatization of Knowledge and Investment in R&D

In spite of the increase in privatization of knowledge, universities are still the major source of biotechnology innovations. They contribute to improved productivity by both transferring technologies directly to existing companies and by spawning new organizations that induce competitiveness. Even when the industry is stagnant and not innovative, innovations that originated in the universities are a source of technological change and competitiveness. However, the process of technology transfer depends on establishing and protecting intellectual property rights. The introduction of patents on genetic knowledge and the process of technology transfer where companies obtain the rights to develop university innovations accelerated the process of technology development. Patenting and privatization provides incentives for investment in technological development. Since university discoveries are in most cases very basic, their commercialization requires significant investment in upscaling and testing, and the private sector will not engage in this investment without assurance that benefits will be captured. Investments of venture capitalists as well as multinational companies in biotechnology research projects depend on their perspective on profitability. Thus, concern about acceptance may lead to reduction in investments. Takeover of start-ups by multinationals at

significant prices actually encourage other investors to take the risk on new biotechnology ventures. On the other hand, the divestment of agricultural biotechnology divisions by life science companies tend to provide disincentives to ventures in this area.

6. The Long-Term Effects of Proprietary Control Over Knowledge

The patenting and licensing efforts of universities appear to have enhanced the utilization of academic discoveries in the short run, but the resulting limits on access to this knowledge may slow innovation in the long run. The ability of researchers in universities and international agricultural research centers to develop and introduce new technologies can be hampered by legal constraints on the use of proprietary knowledge. The human genome data are a case in point because, although academic scientists worldwide made the vast majority of the gene sequence discoveries and the raw data are in the public domain, companies like Celera and Incyte are developing proprietary data management tools and versions of the data, to which they sell access. Academic researchers risk falling behind their commercial counterparts if they cannot gain access, which in the long run may reduce the rate of advances in basic science that are key to future innovation. This situation is already impacting research institutions; in December 2000, the State of Israel, on the recommendation of the Witezman Institute, chose not to buy Celera's genome database because the price was too high given the limitations. Because private firms have actively engaged in acquiring intellectual property rights to tools key to research as well as production, such as agro-bacterium and biolistic genetic modification techniques, academic and non-profit researchers may find their research delayed until they can acquire rights or until patents expire.

One way to address the need for broader access to proprietary technologies is through development of mechanisms such as clearinghouses and cross-licensing arrangements. Common in high tech industries, these mechanisms reduce transaction costs and speed up access to new technologies. Special arrangements may be made to facilitate

biotechnology-based development that addresses the needs of the poor in developing countries.

7. Biotechnology and Developing Countries

In contrast to medical biotechnology, where academic research has been well funded by both the public and private sectors, agricultural biotechnology has received relatively limited funding, and most of the emphasis has been in improving major U.S. crops such as maize, soybeans, cotton, potatoes, and tomatoes. Private investment in agricultural biotechnology has exacerbated this focus, as it emphasizes large markets and high expected returns. Significantly less research effort has been devoted to crops and diseases that are important to poorer regions, although biotechnology innovations, which are embodied in the seed, are perhaps uniquely well-suited to adoption in less-developed areas. Under the current system, the productivity and income gap between farmers in developed and developing nations may increase, even though biotechnology has a significant potential to improve the well-being of farmers in the developing world.

8. Biotechnology and Structural Change

The introduction of biotechnology has been associated with increased concentration in agriculture. The first commercial applications of agricultural biotechnology were in pest control (e.g., Bt cotton, Round-Up Ready varieties) introduced by chemical companies with substantial agricultural pesticide portfolios. Unlike pesticides, however, which can be sold separately, seed-embodied pest control is inextricably linked to specific varieties that are genetically modified to incorporate the innovation. In order to bring their biotech products to market, the chemical companies acquired seed companies, leading increased concentration in the agricultural input market. DuPont, for example, acquired Pioneer Hi-Bred, and Monsanto acquired Holden Foundation Seeds. This trend is likely to continue; the French biotech firm Genset recently declared that it is looking to downstream integration as a means to increase its market power.

While commercial agbiotech introductions have mostly affected agricultural production, researchers are now working on innovations that enhance the nutritional value and other quality traits of agricultural products, and thus the output market. Introduction of these innovations are likely to drive increasing vertical integration for several reasons. On the production side, growers must be convinced to grow these new products and be assured of adequate return, especially when consumer acceptance is unclear. Firms will likely engage in contracting arrangements to reduce uncertainty and facilitate adoption (Lane, 1991). With the first such food product, the Flavr/Savr™ delayed ripening tomato, for example, Calgene provided the seed and bought the output of growers, guaranteeing them a market. These kinds of contracting arrangements have become prevalent in livestock and vegetable production, where price is quality sensitive.

The development of quality augmenting varieties offers the opportunity for increased product differentiation in agriculture. While it remains to be seen whether the added value will noticeably improve farm incomes, it is possible that growers currently producing major commodities that have been subject to oversupply and low prices will augment their revenues with niche products that generate higher returns. To realize the benefits of product differentiation, however, growers will need to achieve more market power in the downstream market, where the food manufacturers and retailers have become increasingly powerful.

9. Biotechnology and Precision Farming

An intriguing issue relates to the complementarity and substitution relationship between biotechnology and precision agriculture. Precision farming technology uses advanced information technologies to optimize the use of inputs. It facilitates, for example, planting of different crop varieties in a single field to adjust for heterogeneity in land conditions and similar variations of pest control applications.

The possibilities that precision farming offers for increasing productivity through optimization of finely tailored seed varieties may generate an expanded market for biotechnology products, especially in areas with sufficient local variation in ecological conditions. In this regard, biotechnology and precision agriculture are complementary, and the diffusion of one will help push forward the diffusion of the other. Seed companies and agrochemical suppliers that promote precision farming in the United States may in the future promote biotechnology products as well, increasing the integration of food and pesticide companies with mechanical input suppliers.

10. Conclusion

The introduction of biotechnology occurred concurrently with, and was affected by, the increased patenting of biological knowledge and greater efforts to transfer technology from the public to the private sector. Establishing proprietary rights to knowledge enhances incentives for commercial development, but may constrain future innovations unless mechanisms are introduced that will allow improved access to technologies. The current patterns of biotechnology development emphasize the needs of producers in developed countries, and the potential of biotechnology to improve agriculture in the developing world may not be realized without greater public investment and policy changes that enhance incentives for these activities.

Agricultural biotechnology has been associated with the integration of chemical and seed markets in agriculture. In the future, the complementarity of biotechnology and precision farming may promote further integration among agricultural input suppliers. While agbiotech-driven vertical integration of input suppliers and increased reliance on contract farming will increase concentration in the agricultural sector, opportunities for product differentiation, however, may allow farmers to improve their incomes. In the end, consumer acceptance will strongly influence which agricultural biotechnology innovations will be adopted and which types of innovations will be developed in the future.

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