Transitions in Agbiotech: Economics of Strategy and Policy

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11. Innovation Dynamics and Optimal Licensing Strategies in the Agro-biotechnology Industry

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Chapter 11

Innovation Dynamics and Optimal Licensing Strategies in the Agro-biotechnology Industry

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Introduction

Much of the literature on intellectual property licensing strategy deals with optimal payoff schemes that maximize the present value of a stream of licensing fees within a particular time horizon. Less attention has been paid to the optimality of clauses that add flexibility to licensing contracts, and also to more discrete decisions, such as whether certain intellectual property portfolios should be licensed or kept proprietary altogether. Furthermore, the connection of licensing strategies and the underlying innovation dynamics has not been given sufficient attention. In this study, we argue that licensing strategies executed in early phases of an innovation's lifecycle should pay sufficient attention to securing flexibility instead of maximizing expected income alone. Failure to observe such a simple rule may have fundamental impacts on the long-term value and longevity of an innovative firm. We use a comparative case study approach within the context of the agrobiotechnology industry to provide empirical context for our discussion.

Intellectual Property and Licensing Strategies

Knowledge has been described as the "new strategic raw material for creating wealth" (Parr and Sullivan 1996). In markets where innovation is a key dimension of competition, management of intellectual assets is critical for long-run business profitability. This is particularly true for technology startups whose output is intellectual property.

To capture innovation rents from their intellectual property and stock of knowledge, firms often use licensing contracts. Much of the economic literature on intellectual property and licensing strategies has focused on payoff schemes that maximize the present value of a stream of licensing fees within a particular time horizon. For example, Yi (1998) examines the optimal licensing policy of a patent holder when potential licensees differ in their capacities to absorb the patented technology. Kamien, Oren, and Tauman (1992) compare optimal licensing strategies (i.e., auctioning, flat rate fee, or per unit royalty) under specific market structures. And so on.

A chief difficulty in deriving optimal licensing strategies for knowledge assets is high value uncertainty (Bessy and Brousseau 1997). Uncertainty in the value of knowledge assets comes in part from asymmetries in informational markets (Arrow 1962), but also from inherent uncertainties in the potential use of the knowledge assets. Many potential uses of new knowledge can not be effectively anticipated. Furthermore, knowledge is itself an input to further knowledge creation. New knowledge can augment or reduce the value of previous knowledge. The cumulative nature of knowledge also creates problems on how to appropriately compensate the contributing parties for their knowledge added. Under such conditions, *ex ante* optimal incentive schemes are difficult to devise. *Ex post*, jointness in the production of new knowledge leads to indeterminate quasi-rent sharing schemes (Alchian and Demsetz 1972). Licensing contracts are therefore characteristically incomplete.

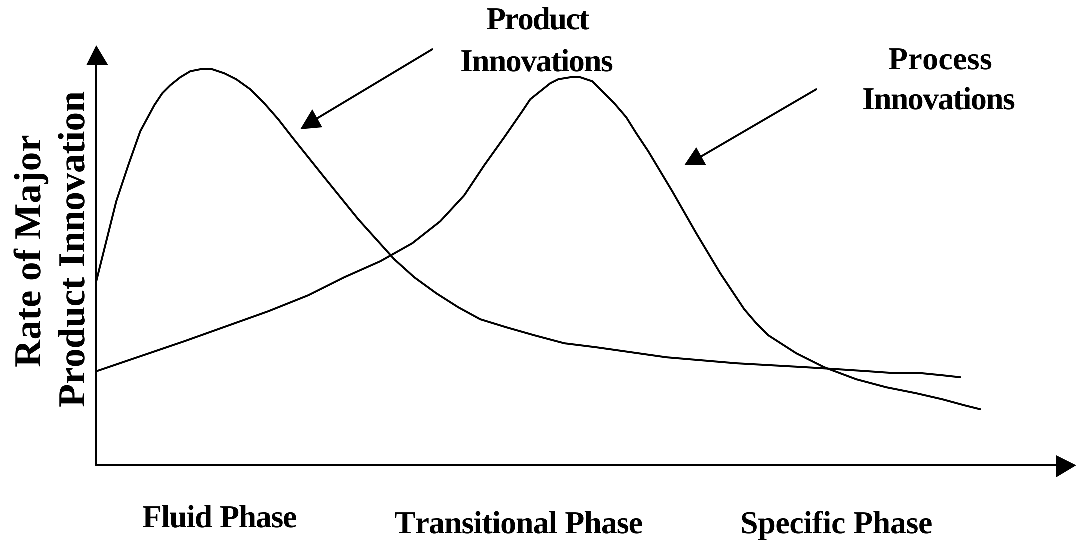
Technological and value uncertainties, however, tend to vary in a somewhat structured way during the various phases of an innovation lifecycle. This suggests that licensing strategies must effectively account for such information. Much along the lines of Dixit & Pindyck's (1994) discussion on real options, when uncertainty is high, flexibility can have significant value. In the early stages of innovation, when technical and value uncertainties are high, safeguard clauses, restrictions on geography and market scope, technology "flowback " conditions, and clauses for contract re-negotiation deserve special attention. Not acting or delaying the decision to license can itself sometimes be very valuable. Accounting for the underlying innovation dynamics is therefore paramount to arriving at optimal licensing strategies.

Innovation Lifecycle and Uncertainties

Utterback (1994), and Abernathy and Utterback (1978) describe an innovation lifecycle, and the associated industry dynamics, through an evolutionary process whereby new industries pass from a "fluid" phase to a "transitional" and, ultimately, a more structured "specific" phase through the emergence of a dominant product concept (a dominant design). The rate of product innovation in an industry is at its highest during the formative years. This is called the fluid phase when a great deal of experimentation with product design and operational characteristics takes place among competitors. Several distinct product concepts and designs may be brought forward at one time. This period of fluidity gives way to the transitional phase in which the rate of major product innovation slows down and the rate of process innovation focused on efficiency improvement speeds up. Product variety gives way to a standard design and product concept. The pace of process innovation quickens and some industries may enter a "specific phase" in which the rate of innovation dwindles for both product and process innovations as firms focus on cost, volume, and capacity (Figure 1).

Mirroring this innovation cycle, firm entry is at its peak during the fluid phase of the product innovation where new entrants compete for the dominant product design. Once the dominant design becomes apparent the total number of firms drops off as the industry consolidates around a few dominant players. These remaining firms are compelled to emulate the features of the dominant product concept. Likewise, the dominant design reduces the number of product performance requirements as they become implicit in the design itself (Utterback 1994: 25).

Figure 1. The Dynamics of Innovation Cycle in New Industries



A dominant product concept or dominant design is not predetermined. Rather, it is endogenous to the innovation process and emerges from a complex interplay of technical possibilities, strategic maneuvering of firms, the occasional configuration and ownership of assets, history and sheer inertia (Kalaitzandonakes and Bjornson 1997).

Within the context of an innovation's lifecycle, technological and value uncertainties for knowledge assets are at their highest levels during the fluid phase. During this phase, knowledge assets may become more or less valuable or even be deemed obsolete through alternative discoveries or through strategic positioning that can turn other, often technologically inferior, innovations into dominant ones. As the fluid phase comes to a close and the dominant design emerges, technical and value uncertainties are sharply reduced. Knowledge assets that are incompatible with the dominant design are abruptly devalued. Knowledge assets that are compliant are valued through emergent markets.

Clearly, licensing strategies should be cognizant of such abrupt changes in uncertainty and asset valuation. Attention on clauses that add flexibility to licensing contracts rather than focusing simply on payoff schemes that maximize income is warranted under such circumstances. Careful consideration of discrete choices (license/no license) is also relevant.

How much of an impact can different licensing strategies have? As we demonstrate below, licensing strategies followed in the early phases of an innovation can be the difference between firm success and failure. To provide empirical evidence, we review the licensing strategies of two agrobiotechnology startups, Mycogen and Ecogen, and discuss their impacts on the success and market valuations of the two firms. We begin by describing the lifecycle of technical innovation in the bioengineered pesticides industry to which these two firms have actively contributed in the last 15 years.

Bioengineered Pesticides:
Innovation Lifecycle and Industrial Dynamics

Mycogen and Ecogen entered the agricultural pesticides market through the opportunities created by the discoveries of recombinant DNA and genetic engineering in the early 1970s. Damages from agricultural pests on the U.S. agricultural production are valued at an estimated $30 billion annually (Office of Technology Assessment). These losses occur despite some $7 billion being expended every year on agricultural pesticides (Association Service Group). For decades, synthetic (chemical) pesticides were the predominant means of controlling key agricultural pests. Since the early 1970s, however, chemical pesticides faced heightened scrutiny for alleged adverse effects on public health and the environment.

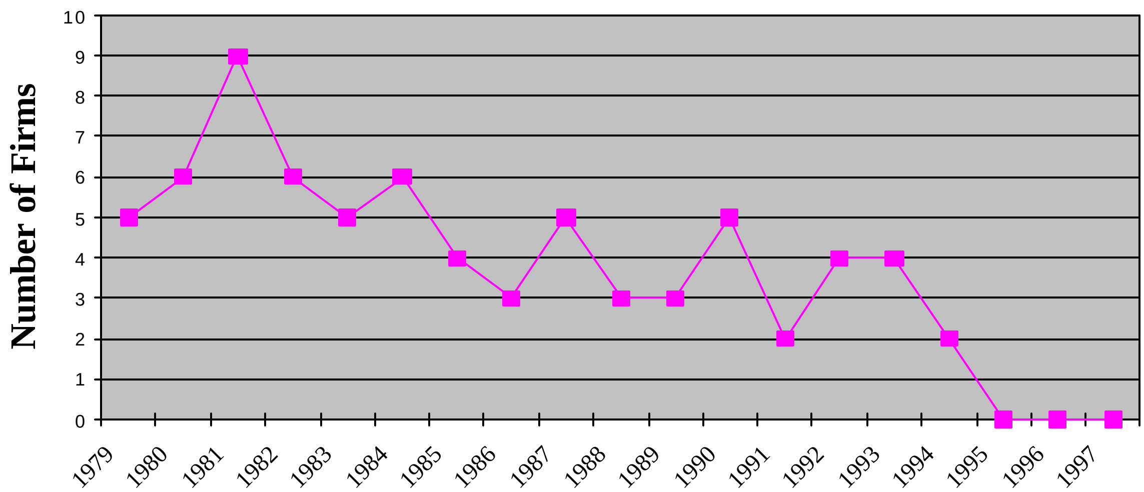
The advent of genetic engineering allowed for a different model of pest control. Bioengineering was envisioned as the fundamental technical innovation that would allow the creation of biological pesticides that are safe, environmentally benign, and effective. Biological pest control, of course, was not a new concept. A variety of predatory and parasitic insects and microbes were used to control insects and mites over the years. However, such biological agents were historically limited by cost and efficacy considerations. Genetic engineering was used to improve the range, efficiency and cost effectiveness of biological pesticides.

A new industry emerged around the new concept of improved biological pest control, with over 70 startups pursuing it in the U.S. alone (Figure 2). Incumbents with long traditions in synthetic pesticides, like Monsanto, Ciba, American Cyanamid, Rohm and Haas, and others, also joined in the new industry by making often-significant investments in bioengineered pesticide research programs. Several competing product forms and designs were pursued in the early stages of innovation. They involved various forms of bioengineered microorganisms with enhanced natural pesticidal action (biopesticides), bioengineered plants augmented with foreign DNA for producing proteins with pesticidal action, and hybrid forms.

Biopesticides include the use of microorganisms, such as bacteria, fungi, nematodes, viruses, and protozoa (Cline and Kalaitzandonakes 1997). *Bacillus thuringiensis* (Bt), a soil bacteria, led the way in research and product development. Different strains were found to have pesticidal action against Lepidoptera (butterflies and moths), Diptera (flies and mosquitoes), and Coleoptera (beetles). Nematodes and pheromones were also broadly researched (ibid.).

Various techniques were used to develop more effective biopesticides through genetic manipulation of microorganisms. Ecogen for example, increased the amounts of active ingredient in Bts by combining different strains. Other companies, like Mycogen, developed “big crystal” strains with a higher percentage of target pests killed by increased toxicity. The delivery mechanisms for biopesticides were also experimented with. The Bt toxin gene was placed in other bacteria that inhabit seed coatings, roots, and surface films where pests feed.

Figure 2. Startups Entering the Bioengineered Pesticide Industry



Other industry entrants like Calgene, Agracetus, Agrigenetics and Monsanto, focused their R&D efforts on augmenting plants with foreign DNA to produce protein with pesticidal action. *Bacillus thuringiensis* genes were inserted through genetic engineering into corn, cotton, potato and other plants to make them resistant to target pests. Plants were transformed to produce the protein in tissues where larvae feed so that coverage and timing of pesticide applications would not be an issue. Transgenic plants were to embody the main advantages of spray-on biopesticides in the most convenient formulation of all: the seed itself.

Few entrants experimented with hybrid product concepts as well. Crop Genetics International (CGI) for example, focused its research efforts on developing "plant vaccines." Crop genetics international's patented InCide technology involved inoculating plants with colonizing bacteria with pesticidal action. This technology was to combine the simpler bioengineering techniques involved in biopesticides and the advantages of transgenic plants in convenience of application and efficacy.

By 1992, the prevalence of transgenic plants as the dominant product concept became apparent. Many of the firms that pursued alternative product forms exited or devalued and failed by the mid-1990s. As product innovation began to subside and gel around the dominant product concept, the industry started to focus on commercialization and to consolidate around few a dominant players (Kalaitzandonakes and Bjornson 1997).

Licensing Strategies in the Bioengineered Pesticide Industry: A Comparative Case

While companies like Ecogen remain as biopesticide producers, market potential for biopesticides is much more narrowly focused, and Ecogen has undergone repeated downsizing since the mid-1990s. In contrast, another biotechnology firm that originally focused on biopesticides, Mycogen, was able to transform itself into a dominant player in the emerging transgenic seed market. Why was Mycogen able to become an industry player while Ecogen was not? They both entered the industry in the very same year, they went public at about the same time, and they developed very similar technology assets. Yet, in 1998, there was a $1 billion gap in their market valuation. As we argue here, part of the explanation for their divergent fortunes lies in their differing licensing strategies during the fluid phase of the bioengineered pesticide industry.

Technology Strategies of Ecogen and Mycogen

Since its inception in 1983, Ecogen invested heavily in biopesticide research and development (R&D). This investment yielded significant technological assets. Ecogen boasted one of the largest private Bt libraries in the world with over 10,000 strains. Such libraries allow broad searches for strains with elevated pesticidal action against species of commercial interest. Ecogen also developed cutting-edge proprietary technology for building novel strains as well as discovering and improving genes with insecticidal action (Cline and Kalaitzandonakes 1997).

Ecogen's first recombinant Bt biopesticide, Raven, showcased its marquee technology (SSR), with two strains of Bt woven together through genetic engineering. Ecogen patented the SSR process creating a high performance bacteria with increased efficacy on a broader scope of insect species. In addition, this system allowed the gene to be manipulated without introducing any foreign DNA – allowing faster regulatory approval (ibid.).

Much like Ecogen, Mycogen focused its initial attention on Bt technology, building an equally extensive library of strains by collecting samples around the world. Its focus was on discovering, isolating, and developing novel Bt genes with pesticidal action against commercially important insect pests. By the mid-1990s, Mycogen and Ecogen together owned over 75 percent of Bt genes and gene patents worldwide (Cline and Kalaitzandonakes 1997, Kalaitzandonakes 1997).

Licensing Strategies of Mycogen and Ecogen

Ecogen and Mycogen took quite distinct approaches, however, to licensing their technology assets. Ecogen used its technology to develop its core business of biopesticides and licensed it for other uses and markets to dominant companies where returns could be maximized. In 1991, certain Bt genes were licensed to Pioneer Hybrid, the leader in the global seed industry, for the development of transgenic plants in exchange for a fee of $350,000, and royalties on the sale of any seed corn containing these genes. During the same year, the company signed a similar licensing agreement with Monsanto. This agreement was also for in-plant use of five Bt genes, giving Ecogen royalties on the product sold (Cline and Kalaitzandonakes 1997).

In contrast, Mycogen pursued a different licensing strategy. Despite numerous R&D agreements and strategic alliances with large firms, Mycogen never transferred rights to its technology to any of its partners. It often ceded equity rights to the entire company, as well as exclusive marketing rights to one or more markets which were mostly outside the U.S. Maintaining exclusive proprietary rights to its key technology assets in the early phases of innovation, proved to be key to Mycogen's long term success.

When, in the early 1990s, transgenic plants emerged as the preferred way to leverage advances in the bioengineered pesticide market, Mycogen was able to switch its research focus. In 1992, Mycogen acquired Agrigenetics, a company with a strong base in plant transformation technology and a substantial seed distribution business it had pieced together through acquisitions of several regional seed companies. Through this acquisition, Mycogen tied-in its key technology assets (the Bt genes), with potent plant transformation technology and a distribution system (Kalaitzandonakes 1997). Ecogen, was unable to execute a similar strategy as it had already given up rights to its gene technology in the emerging transgenic seed market through its licensing agreements.

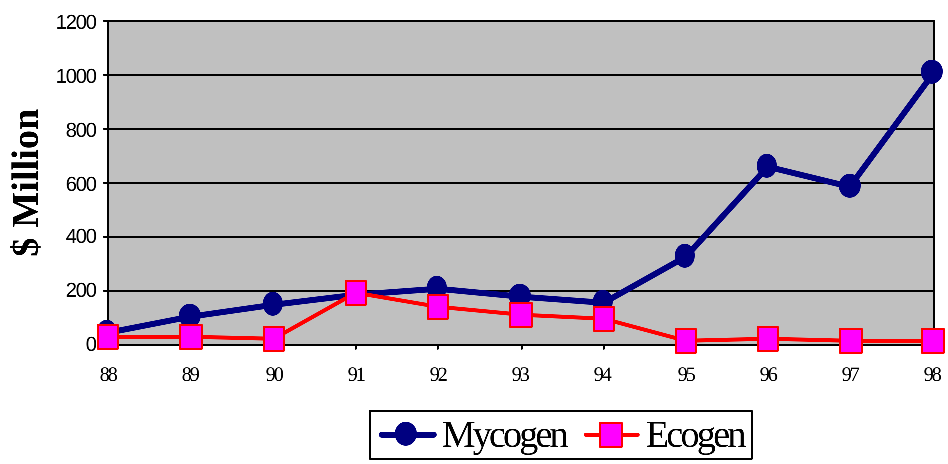
Following this strategic shift in its R&D focus, Mycogen turned its attention into developing its transgenic seed business by continuing to leverage the importance of its gene technology and associated property rights. In 1993, Ciba Seeds and Mycogen signed a cross-licensing agreement on Bt corn. Ciba offered Mycogen the corn seed it had genetically engineered for resistance against European corn borer as well as access to extended work on the toxicology of Bt in exchange for freedom to operate. Ciba’s transgenic seed corn was infringing on Mycogen’s patented gene technology. Through this agreement, Mycogen leapfrogged the competition and in 1995, along with Ciba, was first to market with its transgenic Bt corn (Kalaitzandonakes 1997).

In 1995, Mycogen signed a 10-year product development agreement with Pioneer Hybrid. Under this agreement, Mycogen would contribute its Bt gene technology in exchange for Pioneer’s expertise in plant transformation and its enormous capacity for product development. Mycogen’s genes would be placed into each company’s proprietary germplasm across many crops of interest. For each transformed product, both companies were obliged to reach the market at the same time. Hence, through this co-exclusive right Mycogen was able to expand its product line capacity, allowing it to genetically engineer multiple crops and parent lines simultaneously. It effectively shortened Mycogen’s timeline of new product introduction by several years (Kalaitzandonakes 1997).

Market Valuation and Business Prospects: Mycogen and Ecogen

Figure 3 provides market valuations of both companies over the 1988–1998 period. What is apparent from Figure 3 is that Ecogen’s market valuation paralleled that of Mycogen in the fluid phase of technological development and beyond. However, once transgenic crops approached commercialization, the market valuations of the two companies started to diverge. At acquisition in 1998, Mycogen was valued at over $1 billion, while Ecogen was valued at $15 million. We argue here that the differing licensing strategies of the two companies can at least account for a significant part of the differences in the valuation of the two companies. Mycogen through its licensing strategy before the emergence of the dominant design was able to react to a changing technology market and leverage its technology assets. Ecogen, through its licensing strategy, had already executed the option on its technology assets.

Figure 3. Market Valuation of Mycogen and Ecogen



Biopesticides may still have opportunities in niche markets. With lower R&D costs, as well as regulatory costs, natural pesticides can compete with synthetic pesticides and transgenics in some niche markets. This is particularly the case with high value crops where biopesticides are attractive for controlling pests which otherwise would cause cosmetic injury to the crop (Cline 1998). In addition, recent events in Europe – with several countries placing either specific bans or moratoriums on transgenic crops -- may give biopesticides a short-run advantage over transgenic crops. In particular, organic farming is being actively promoted in Britain with farmers eager to switch to crops that command a premium price in stores. Biopesticides are considered to be the only pesticides that can be used in organic production because they are "naturally" occurring.

Concluding Comments

In this paper we have argued that licensing strategies should be explicitly tied to innovation dynamics. The prevailing focus of licensing contracts on royalty fees and payoff schemes is justified in the later of innovation where technical and valuation uncertainties are drastically reduced. In the early stages of innovation, attention to be flexible licensing contracts and to discrete decisions, such as postponing licensing is warranted. As we have argued here the value of the option on technology assets may be very high in the face of extreme uncertainty. It was in the cases of Mycogen and Ecogen.

Endnote

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