AgBioForum, 11(2): 71-81. ©2008 AgBioForum.

Insiders' Views on Business Models Used by Small Agricultural Biotechnology Firms: Economic Implications for the Emerging Global Industry

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The source of most innovations coming from the emerging agricultural biotechnology industry is small and medium enterprises (SMEs), yet SMEs have a high failure rate, which raises questions, such as "is there some flaw in the business structure of firms in the industry?," or "is the economic and policy environment facing the industry not conducive to supporting SMEs?" The types of business models used by SMEs across the globe are identified using "insider information" collected from interviews of senior managers. Results have implications for economic development because the economic and policy environment is found to be the constraint.

Key words: agricultural biotechnology, business models, emerging industry, interview, risk.

Recent and on-going scientific discoveries have given birth to an emerging industry called "agricultural biotechnology," which is attracting much attention around the world due to the industry's expanding impact on the productivity of commodities used in food, industrial, and pharmaceutical products. That impact is expected to be even more significant in the future. However, that future success is not certain. An emerging industry is full of unknowns. *Investopedia* (a web-based financial dictionary) defines "emerging industry" as "an industry, usually formed by a new product or idea, that is in the early stages of development." It goes on to explain that

> "there is a lot of uncertainty in emerging industries as demand for the product, the growth potential and market conditions of the industry are unknown and there is a limited track record. Companies in an emerging industry tend to have little or no positive income while trying to raise enough money for research and development to progress growth. Companies in these industries are highly speculative as both the companies and the industry itself have yet to establish themselves in the larger market."

Agricultural biotechnology is unique compared to most emerging industries in that it is developing simultaneously in many countries around the world and, in some of those countries, there already exists one or more very large firms that has established itself in non-agricultural biotechnology and is diversifying into this relatively new market. Nevertheless, the source of much of the new technological innovations coming from the agricultural biotechnology industry is small and medium enterprises (SMEs),[1] which are research-intensive in their activities and very fragile in their existence (Organization for Economic Cooperation and Development [OECD], 2008). SMEs have a high failure rate, which raises several questions, such as "is there some flaw in the business structure of firms in the industry?," "is the economic and policy environment facing the industry not conducive to supporting SMEs?," or "is competition simply to blame?" Questions such as these have significant implications for the emerging global industry and for the agricultural producers that might be served by the industry. Unfortunately, virtually nothing is known about the business models being used by firms in this industry (OECD, 2008). Therefore, the Organization for Economic Cooperation and Development commissioned this study to contribute to the discussion of agricultural biotechnology and its future by presenting some new descriptive data that address these issues.

The primary objective of this study is to identify the types of business models being used by small and medium enterprises in the agricultural biotechnology industry as it exists across the globe. A secondary objective is to identify some of the economic and policy factors that influence the business opportunities available to SMEs. Both objectives are evaluated using "insider information" collected from telephone interviews of senior managers from agricultural biotechnology firms located in countries scattered across the globe. Finally,

1. *The Organization for Economic Cooperation and Development defines "small and medium enterprises" in agricultural biotechnology as firms with less than 250 employees.*

some of the economic implications of the results will be highlighted. Although this study is primarily descriptive, the initial observations presented here can help frame the future discussion.

Background on the Industry

The agricultural biotechnology industry is relatively new, but its potential impact on agriculture is great. For example, Falck-Zepeda, Traxler, and Nelson (2000) found that an early product of biotechnology research, Bt cotton, generated US$240 million in economic benefits when it was introduced in the United States in 1996, with 59% of those benefits going to US farmers. That study and others, such as that by Giannakas and Yiannaka (2008), found that consumers also benefit from the introduction of biotech products into the markets for food and other consumer goods. As a result, future market prospects for agricultural biotech products are expected to be increasingly strong as consumers learn more about the economic benefits of, and the science behind, these products (Lockie, Lawrence, Lyons, & Grice, 2005). With consumer acceptance gradually expanding, the markets for agricultural biotechnology products will offer farmers in both wealthy and poor countries economic incentives to switch their production from conventional to biotech products (Hillyer, 1999; Spielman, Cohen, & Zambrano, 2006). However, there are significant differences in the rates of consumer acceptance of these products across countries, so many policy issues remain that influence the future of the agricultural biotechnology industry (Breustedt, Muller-Scheebel, & Latacz-Lohmann, 2008; Sheldon, 2002).

The industry itself is dynamic, with rapid turn-over of small- and medium-sized firms, while a few large firms dominate. Consolidation in agricultural biotechnology has been intense, causing many SMEs active in developing plant varieties to be bought up, merge, or disappear (Brennan, Pray, Naseem, & Oehmke, 2005; Johnson & Melkonyan, 2003; Joly & Lemarie, 1998; Oehmke & Wolf, 2003). This contrasts with health biotechnology, where there are thousands of SMEs, many of which play a major role in product development. A study by Marco and Rausser (2008) found that acquisition of patent rights has been a driving force behind many mergers of large and small firms in agricultural biotechnology.

The unique structure of the agricultural biotechnology industry leads to business behavior characterized by economic theory as reflecting an imbalance in the market power of individual firms within the industry. It is well known that in any industry, firms with relatively less market or "bargaining power" are disadvantaged in their contacts with firms holding more market power and, as a result, will be less profitable (Lanzillotti, 1960). Firms with lower profit margins are more susceptible to failure over time compared to more profitable firms.

Industries with imbalances in market power across firms are prone to certain types of business behavior that aim to increase the power of individual firms. In other words, an industry's structure influences its behavior, and this is true in biotechnology also (Fulton & Giannakas, 2001). Some of the types of business behavior occurring in agricultural biotechnology industries in the most developed countries include strategic alliances and other forms of collaboration between firms, and vertical and horizontal coordination. Strategic alliances are temporary, sometimes informal, agreements between firms to team up to accomplish some end result that benefits all firms involved (Traill & Duffield, 2002). Formal alliances involve contractual agreements, while informal alliances can involve simply a "gentlemen's agreement" between senior managers of two or more firms. Many other forms of collaboration between firms exist in the agricultural biotechnology industry. These range from "partnering" arrangements between groups in the private and public sectors (Horsch & Montgomery, 2004) to joint ventures and subcontract out specific activities from one firm to another (Chiesa & Toletti, 2004). Finally, vertical and horizontal coordination within a supply chain can occur through formal arrangements between firms or through merger and acquisition activities between firms that result in the creation of a single, larger firm that performs the different functions once performed separately by the merged firms (Kalaitzandonakes & Bjornson, 1997). A common example of vertical coordination in agricultural biotech is formal vertical integration in which two firms merge: one firm performing the product development research and the other firm performing the market development business activities.

The general economic nature of an industry like agricultural biotechnology is understood fairly well, but the specific nature of business decision-making at the firm level has not received much attention in this emerging industry (Altman, Klein, & Johnson, 2007). It is likely that differences at the firm level may explain the contrast in structures of agricultural versus non-agricultural biotechnology industries. That hypothesis remains to be tested. This study provides information relevant to this question that offers much insight into the issue, but

the information reported here is not sufficient for formal testing of this hypothesis.

Background on Firms in the Industry

Agricultural biotechnology firms range in size from tiny research groups of just a few people with zero revenue to huge multi-national conglomerates with revenues totaling billions of dollars each year. There are very few of the large firms operating in the global market at this time, but there are numerous small- and medium-sized enterprises trying to gain a stable place in the separate industries developing in many countries. This study focuses on those SMEs.

Little up-to-date information is available on the business models and strategies of small firms. Around the turn of this century there was a small flurry of studies that tried to anticipate what biotech firms would become as the industry matured (e.g., Begemann, 1997; Chataway, 2001; Mangematin, Lemarie, & Catherine, 2001). However, since that time very little detailed analysis of biotech business behavior has been done. We do know that risk management is a significant factor in the decision-making of agricultural biotechnology firms and their customers (Wilson, Dahl, & Maxwell, 2007). Given the relatively weak market power position of small and medium enterprises, as noted above, agricultural biotech firms must identify and manage the many unique sources of risk facing them or they can quickly be put out of business. To evaluate the world's agricultural biotechnology industry's future, it is necessary to understand the management plans of firms in that industry. Therefore, this study contributes to that understanding by gathering and interpreting information about SMEs from firms scattered around the globe.

Method of Analysis

In agricultural biotechnology, which thus far has an unusual structure made up of a few very large firms and a great many firms that are small and not well established in a market, the patterns of business behavior are also not well established. It appears that the availability of expertise and funding drives an agricultural biotechnology firm's conduct, in terms of what functions it conducts. That, in turn, drives the structure of biotech firms and, subsequently, the industry itself.

Therefore, this study seeks to identify business models used by SMEs. A major component of identifying business models used by biotech firms will include identifying what business functions are performed "in house." That type of information can come only from people inside a firm. Thus, this study uses primary data to accomplish its goals.

The best source of information about the business plans and behavior of a firm is the business managers directing that firm. So, telephone interviews were conducted with senior managers of small and medium agricultural biotechnology firms in several countries.

The firms included in this study were selected from a stratified list to assure a sampling from different continents and from different segments of the agricultural biotechnology sector. To begin, a list of firms in the evolving global industry was identified by the OECD. That list was given to the author by the OECD. Next, a stratified breakdown of those firms was developed to make sure there was representation from the industries in North America, Europe, and elsewhere. Finally, a second stratum was developed within each continental industry by categorizing firms by the types of product markets they served (although each firm was involved in agricultural biotechnology). Firms from each category in each stratum in the list were selected by the OECD to be invited to participate in this study. Approximately 30 firms were invited to participate in this study. Those firms are located in North America, Europe, South America, and Australia-New Zealand.

Interview Results

A total of 20 interviews were conducted during March and April 2008, with 19 of those providing complete responses. That translates into a total response rate of more than 60% for the firms that were sent an invitation to participate. Information was collected from firms located in the United States, Canada, Germany, Denmark, France, New Zealand, and Australia. The United States has far more agricultural biotechnology firms than any other country, so 40% of responses came from US firms scattered across all time zones in the country. It is worth noting that most US firms are located near universities that have active agricultural biotech programs, with northern California having the largest cluster of firms.

Characteristics of Firms in the Study

The firms interviewed in this study are all considered small or medium enterprises, yet there is a wide range of economic sizes within this sample.[2] As shown in Table 1, the total value of business assets, total revenues per year, and the research and development portion of each firm's annual budget vary significantly. The best perspective of a typical firm interviewed is reflected in the

Table 1. Summary of responses to firm size questions.

	Average	Highest	Lowest	Median
Total asset value (US $M)	45.4	200	1.5	27
Total revenue in 2007 (US $M)	15.9	103	0	2
Total revenue expected in 2008 (US $M)	18.3	120	0	2.1
Percent of total budget in R&D	71.1%	100%	5%	75%
Number of employees	40.5	249	3	23

"median" response, reported in the last column on the right side of Table 1. It shows that SMEs are typically operating with about $27 million worth of assets, yet they are currently generating only about $2 million in annual revenues. That gives an asset turnover ratio of about 0.07:1, which is very low.[3] Such a result is common in relatively new, not-yet-established firms that are not able to utilize their assets efficiently, in a financial sense. In contrast, a well-established industrial firm with successful product markets will usually have an asset turnover ratio of well over 1:1 or 2:1. Three of the firms interviewed had ratios of over 1:1, with the highest being 1.71:1. That indicates it is quite possible for agricultural biotechnology firms to operate efficiently once they have mature products accepted by the market.

It is enlightening to note that most firms' current focus is not yet on the market for its products, but still on developing those products. The results show that 84% of the firms in the sample are focusing mostly on product development, rather than on marketing of products, with 16% having about equal focus on these two activities. This is another strong indicator that these SMEs are early in their business evolution. That evolutionary process begins with an idea for a product, and then progresses to the development of a product, followed by the introduction of that product to the market. If the market accepts the product, the last stage of a small or medium firm's evolution is to expand its product line to increase its profit total. Successful expansion of product lines often leads to growth of the firm's sales and/or licensing revenues to such an extent that the firm becomes "large" in size and in its market presence. A large firm would usually indicate that its focus was more on marketing of products, even though it may still have a significant product development effort underway.

Table 2. Summary of responses to revenue source questions.

	Percent of "yes" responses
Do you produce and/or market products?	58%
Does your firm sell services?	37%
Does your firm license its technology to other firms?	79%

Most of the firms interviewed indicated that they are using a "portfolio" approach, rather than a "specialization" approach, to product development. The fact that 68% of firms answered this way shows that risk management is a concern to them. A "portfolio" approach to product development was favored by these SMEs because it enabled them to spread their market risk by leveraging their intellectual property across multiple markets. Interviewees acknowledged that eventual market acceptance was uncertain for each of their products, even those products already in the market, so the firms were trying to increase their chances of having at least some market success by entering as many product markets as possible given their financial constraints. This approach is aimed at reducing the firm's "risk of ruin"—the chance that the entire firm would fail.

The stage of the firms' evolutionary progress and the markets those firms are targeting are indicated in the responses to questions summarized in Table 2. Those responses are typical of an emerging industry with firms still very early in their evolution. Whereas a large firm would receive almost all of its revenues from marketing products, the information in Table 2 shows that most firms are relying on other sources for their revenue. Only 58% of the SMEs interviewed have a product that can be marketed. This reinforces the point made earlier that all of the SMEs are still focusing mostly on product development. However, this raises the question of how the firms gain the cash flows necessary for paying their operating costs. Table 1 shows that annual revenues

2. *A twentieth firm was interviewed to augment the data collected from SMEs. The twentieth firm is a cooperative of consultants that advise SMEs, but it is not a SME itself. Thus, no data from that firm are reported in the tables and other statistics in this report; only comments from the firm are used to help express issues.*
3. *A basic asset turnover ratio is calculated as annual revenues divided by the total value of the assets used to generate those revenues. This ratio is considered to be an indicator of the operating efficiency of a firm.*

were as low as zero. In fact, one-third of the firms interviewed had zero or nearly zero annual revenues. For those firms, certainly, and possibly all SMEs, some other sources of cash flow are necessary for continued survival. One source is acquiring capital from investors. If that is the only source of funds for a firm, it requires that the firm have a "burn rate" low enough to give them sufficient time to develop a product and/or technology that can be marketed before funds run out, forcing the firm to liquidate. Clearly, relying only on investor capital for cash flow is a high-risk strategy that managers want to avoid if possible. Therefore, SMEs look for other sources of revenue as soon as they can be developed. The two most common sources of revenues, in lieu of product sales, are revenues from the sale of services and licensing fees collected from other firms. As shown in Table 2, only 37% of the SMEs interviewed sell services to customers. Those that do use this approach to increasing revenues all sell contract services that are tailored to customers' needs. The services are almost all research-based, deriving value from the scientific and technical skills of the firm's employees and facilities. However, more than twice as many SMEs interviewed use a licensing approach to raising revenues. This approach requires that a firm have a "completed" product or procedure that it allows other firms to use or sell in exchange for a licensing fee. Whereas selling services requires only people or facilities, selling licenses requires some unique intellectual property (IP). Thus, licensing is viewed as an intermediate step between developing a product and marketing that product "in house." A small firm with some (usually patented) IP, but without sufficient capital or market access, may choose to license that property to another firm, which will then take the property to market. In this approach, both firms share in the sales revenues derived from the final product's market; the SME that developed the IP gets a license fee paid by the marketing firm from the revenues received. The amount of the licensing fee is negotiated between the two firms, so the relative amounts of bargaining power held by each firm will influence the relative shares of the property's market value being captured by each firm. Finally, it is worth noting that all but one of the zero/low-revenue firms interviewed raised revenues through either selling services or licensing. Also, every firm except two used at least one of the two approaches for raising revenues. One firm that neither sold services nor did licensing had $20 million in revenues in 2007 and expected product sales revenues to increase by 35% in 2008. This is consistent with the hypothesis that firms would prefer to capture all of the market value of their IP themselves, rather than share that value with other firms through licensing. So, it appears that SMEs in the high-risk agricultural biotechnology industry will bear all of the market risk in their products as soon as the firm believes its "risk of ruin" is sufficiently low. That change in risk exposure comes from being established in the market with one or more products.

Table 3. Cross-participation in segments of the biotech industry.

	Food	Biofuels	Health
Percent of total firms surveyed	37%	16%	32%
Share also in Food	–	67	67
Share also in Biofuels	29	–	33
Share also in Health	57	67	–
Share in all three sectors	29	67	33

Note. The top row shows the percentage of the total sample that participates in the segment named by the column heading. The "share" percentages indicate what portions of the firms in the segment named by the column heading are also in the segment named in the row.

Table 3 provides some insight on the degree of small firms' risk diversification through cross-participation in three of the largest market segments in the biotechnology industry: food, biofuels, and health (pharmaceuticals). The top row of the table shows the percentage of the entire sample of firms interviewed that participate in the segment. Of those firms participating in the segment listed at the top of the column, the share of those that also participate in one of the other two market segments is presented in the second through fourth rows. The bottom row of Table 3 shows what share of firms in the segment listed at the top of the column are also in both of the other two segments. For example, 37% of all firms interviewed participate in the food-market segment. Of those firms, 29% are also in the biofuels segment, and 57% are also in pharmaceuticals. The bottom row shows that 29% of firms in the food segment are in all three of the market segments highlighted in the table: food, biofuels, and pharmaceuticals. In general, the significant amount of cross-participation of SMEs in different market segments makes it difficult to categorize firms into unique "application fields," such as a pharmaceutical firm or a biofuels firm. In other words, in non-agricultural parts of the biotechnology industry firms may specialize in one market segment, with regards to the types of products created, but firms in agricultural biotechnology appear to intentionally diversify their market participation by creating products in multiple

segments. As a result, there does not appear to be unique firm or industry structures for each segment in agricultural biotechnology. This issue is considered further in the next section.

Industry Competition and Composition

The level of direct competition between firms in the agricultural biotechnology industry is low in each of the countries represented in the sample of firms interviewed. When asked to estimate how many domestic firms were direct competitors to them, the median response was "3," which indicates that SMEs believe that only a handful of domestic firms compete with them. Similarly, the median response of "7" to the question asking for an estimate of how many foreign firms are competitors to them shows that few foreign competitors participate in the same market segments as the SMEs interviewed. Both of these results are consistent with a fairly well-segmented market for a "branded" product. This implies that each firm not only adds value to the basic commodity with the application of its intellectual property, but, in doing so, they are fairly successful in differentiating their product from that of other firms. In fact, two-thirds of the non-US firms interviewed responded that they had zero domestic competitors. On the other hand, every firm but two in the entire sample said it had foreign competitors. This indicates that the markets for agricultural biotech products are international in nature and that increased global competition can be expected as the industry grows.

Business Opportunities for the Industry

The dynamic structure of the industry has changed business opportunities available to SMEs over time. Interviewees were asked to express their opinions on several factors that are usually seen as significant in shaping the industry.

The first "driver" of business opportunities for small and medium enterprises in the agricultural biotechnology industry is university biotechnology programs. These programs exist in major universities in most wealthy countries. They are diverse in their content, but most include basic and applied research efforts, many of which have potential for applications in biotechnology for agriculture and non-agricultural fields.

Interviewees were asked, "do university biotechnology programs aid or hinder the market?" Sixteen of the 19 firms responded "aid," one firm replied "hinder," one firm said the answer could be both "aid" and "hinder" depending on the content of the university's program, and two firms (one in Europe and one in Australia) were uncertain and did not answer. The one firm that responded "hinder" is located in France. The negative perspective on university programs was apparently due to the fact that "there are almost no more university programs in France for agricultural biotechnology." In every other response, university programs were viewed favorably because "universities are technology developers, the basis for startup firms." Also, another respondent noted that "genetic tools come from universities." In all cases, there was support for continuing the basic research done by universities because commercial biotech firms cannot afford to do that type of science, even though it is key to the development of new biotechnology and new products.

Next, respondents were asked directly, "what factors have caused a change in business opportunities for agricultural SMEs in the past?" Many factors were identified by most firms. The response most common (from 68% of the firms interviewed) was that the cost of applying biotechnologies has increased significantly and, at its current levels, is a constraint to business opportunities. Many firms commented that one of the biggest costs they encounter is the legal and related expenses involved in satisfying all of the regulatory requirements for biotech products. One firm noted that "regulatory hurdles have increased," while another firm said the "regulatory environment is very strict and has lengthened timelines and raised costs." One firm estimated "the cost is US$35-40 million to develop and market a product." However, another firm noted that there is a positive aspect to the legal hurdles faced in that "patents add to market stability." Finally, the high costs of developing an agricultural biotech product and getting it approved for the market affect large firms as well. Those effects result in increased opportunities for small firms to collaborate with larger firms. One respondent offered an explanation: "the economics of large firms are causing them to subcontract out research to SMEs. Large firms are trying to reduce fixed and variable costs and that means they have fewer people, which shifts the research agenda of large firms."

Business Models Used by SMEs

A business model is a combination of a firm's structure and its strategies for accomplishing its short- and long-term business goals. With this loose definition in mind, it is clear that no two firms will have exactly the same business model in use. However, in every industry there will be similarities in the strategies used by groups of

firms. By clustering firms with similar strategies, the general model used by each group of firms can be labeled to help identify patterns of business behavior within an industry. The process of categorizing the different business models used by agricultural biotechnology firms is done later in this paper. In this section, interview responses are reported that provide insight into the business strategies being used by SMEs as part of their business model.

To begin the discussion of business models during the interview process, respondents were asked "in your experience, what types of business models are SMEs currently using?" It quickly became clear that most respondents' answers focused on the business strategies and general business behavior of their firm. Respondents' comments showed that some patterns of behavior are well-known by people in the industry. One response captured the big picture very succinctly: "SMEs are trending toward being a technical supplier to bigger firms. More partnerships are being seen. There is no standard model for SME success." Other comments that identified a strategy or pattern of business behavior are summarized in the sub-sections which follow.

Technology Suppliers. Comments from several respondents showed that their firm was still early in its evolution and is focusing on the research involved in developing something that could be taken to the market by another firm. For example, one respondent said "SMEs are often trying to develop technology that can be sold to a large firm." Another firm said they "focus on technology to sell to other firms for marketing." This strategy was labeled as "niche players."

Dancing with the Titans. Early in a firm's evolution it faces resource limitations, so a common strategy is to collaborate with other firms. As one response explained, SMEs "form strategic alliances with technology partners, thus enabling specialization. Outsourcing is used widely. They learn to 'dance with the titans'." This phrase was coined by the firm in referencing the risks of collaboration with a large firm: watch your step or you can accidentally get squashed by a move of the larger firm. Other respondents made similar comments, such as "SMEs are opportunistic in collaborating or partnering with large firms. SMEs have little vertical integration." Reducing research and development costs and accessing additional human and financial resources were often cited as reasons for using this strategy.

Risk Spreading. All SMEs interviewed were aware of the risky nature of the agricultural biotechnology industry, yet few of them dwelled on risk in their comments. One firm did offer some discussion of how risk management is a factor in its business model. That firm "uses horizontal integration of functions to spread risks. Thus, when the market for one function declines, other function markets can help the firm maintain its staffing and levels of other resources."

Blended Models. One respondent described how the business model used by a firm evolves as the firm develops and shifts strategies. What the respondent called a "blended model" is a combination of the strategies described in the above sections "Technology Suppliers" and "Dancing with the Titans," with the result including a risk-spreading component, such as that described in the section entitled "Risk Spreading." The respondent summarized the situation facing SMEs as follows.

> "There are three models, creating options as the three are blended as a firm develops from one to the next: (1) take out first crop IP and license it to bigger firms, (2) joint venture with another firm that can do the marketing of the product developed from the IP, and (3) use plan #1 blended with slowly doing more product development on their own—'self-developed' products."

The first model mentioned in the comment is the high-risk stand-alone strategy that is virtually forced on new firms that have not yet established themselves as having marketable intellectual property. Once a firm has developed some technology with market potential, it can attract collaborators, as noted in the second model. The third model requires an established market for a firm's products, plus significant cash flows to enable the firm to risk developing products and marketing them in another stand-alone strategy.

Summary of SME Behavior and its Downside. A brief summary of the most common business model used by SMEs in agricultural biotechnology was offered by one interviewee. He also pointed out that the model has a downside.

> "The general model: develop technology to license to other firms for them to market resulting products. SMEs are in a race to develop technology as they burn money. The regulatory costs

> constrain how many firms can take technology to the market. SMEs often take small amounts of money in deals due to their low bargaining power versus larger (vertically integrated) firms during negotiations. Most SMEs take 'front-end' deals to capture some revenue, enabling their continued survival. However, 'back-end' deals are much more profitable for a SME in the long-run."

What the respondent calls "front-end" deals are those in which the firm that developed an intellectual property takes some fixed amount or share of the sales revenues resulting from the marketing of that property by a second firm, and the terms of the deal are negotiated before the property goes to market. Such a deal usually has a limit on the amount to be paid to the SME that developed the property, and payments are usually made prior to the property's market introduction. A "back-end" deal is negotiated with terms that do not limit the amount received by the SME, but the payments are usually made after the property is marketed. As noted in the comment, back-end deals are usually more profitable for the SME when products are successful. Yet, SMEs more often take front-end deals because their weak financial base forces them to take the "guaranteed money" early rather than wait and risk getting some uncertain amount later. This outcome illustrates the weak bargaining position of SMEs caused by their financial constraints.

Business Models and Their Implications for Agricultural Biotechnology

The interview results reported for this study contain considerable information, which enables a detailed categorization of the types of business models small and medium enterprises are—and will be—using in the agricultural biotechnology industry. A brief categorization of these business models is presented next, followed by a few of the implications of these results for the industry.

A Typology of Business Models in Agricultural Biotechnology Firms

A typology of business models derived from the interview information includes three basic types of business models: research-intensive startups; sustainable firms; and large, diverse firms. Within the first two types are separate categories of business models. These are differentiated using the simple definition of "business model" as being a combination of a firm's structure and its strategies for accomplishing its short- and long-term business goals. The basic typology follows.

Research-Intensive Startups. Startups are high-risk/reward attempts to capture some intellectual property that has value to other (usually larger) firms that can develop a market for some product that includes the IP from the startup firm. This type of firm may have zero or low levels of sales revenue. A very high share of the operating budget for such a firm goes to research and development activities. They build patent portfolios and license rights to their IP to large firms. Capital is the greatest constraint on these firms. Capital for this type of firm usually comes from private investors. There are two categories of startups:

- *High-risk startup*: its "burn rate" versus its fundraising is a race for survival, with failure (i.e., operations cease) due to insufficient funds possible within a year.
- *Low-risk startup*: strong fundraising assures multi-year survival.

Most new agricultural biotechnology firms begin as a high-risk startup. These firms are often spin-offs from university biotechnology programs and often maintain close relationships with one or more universities. At this stage of its evolution, the firm is usually science-oriented and very narrowly focused, with the scale of its operations dictated by its level of fundraising. The source of failure of this category of firm is almost always insufficient funding.

A low-risk startup firm is one that has gained access to sufficient funds to cover operating costs for a long enough time period to enable product development activities to be completed. These firms are still very narrowly focused, applying only a few technologies to a narrow range of products.

Sustainable Firms. Firms of this type are self-sufficient, being able to fund their operations from sales revenues and/or licensing fees. There are three categories of sustainable firms; the first two categories include firms operating independently, and the third category includes firms that are integrated with others in some way:

- *Specialized SME*: a firm limited in its ability to diversify due to limited access to either elite germplasm, "brainpower," funding, or markets.
- *Horizontally integrated SME*: a firm with a portfolio of products from a narrow range of technol-

ogy, or they offer varied technologies or research services.

- *Vertically integrated SME*: a firm partnering with one or more other firms through formal participation in a cooperative effort, or fulfilling a formal business relationship described in a contract, or cooperating with another firm under the same ownership.

The first stage of evolutionary growth from startup business models is the specialized SME. This category of firm has some product or technology in the market and is receiving sufficient revenues to be self sustaining, but only because it has a licensing agreement or some type of alliance with a larger firm that handles market development activities. In other words, this category of firm performs a narrow range of activities, including implementing only a narrow range of technologies.

A horizontally integrated SME still may be involved in only a narrow range of activities or technologies, but they have expanded their market access by applying those technologies to a wider range of products. This business model reduces the market risk exposure of the firm by diversifying into different product markets.

A vertically integrated SME is formally linked to other business units that perform different business functions, thus enabling all integrated units to benefit from the revenues earned from the performance of each of the diverse functions. This business model reduces the risk exposure of the firm by diversifying into different sectors of the market for a product.

Large, Diverse Firms. These firms use both horizontal and vertical integration methods to diversify their risks across markets and across business functions.

Local Implications of the Results

A couple of significant implications can be drawn from the information gathered in this study. The first is that R&D do not always go together. In agricultural biotechnology, the two tasks are often performed by separate firms. The single most common reason for that separation of activities is that small firms do not have the financial resources to perform more than one task, so they specialize in either research or development activities. This is a highly risky structure for an industry and an undesirable situation for firms within the industry. At the industry level, this structure virtually guarantees continued high levels of turn-over as specialized firms fail or otherwise disappear. At the firm level, the risk of failure is higher for specialized firms, so there is some urgency to expand through horizontal and, possibly, vertical integration. Relatively new firms are usually able to integrate only through some collaboration with a larger firm. Whether the collaboration is accomplished through either formal or informal alliances, partnering agreements, or contracts, the financial results tend to favor larger firms over SMEs. This does not breed stability.

The second prominent implication drawn from the interviews was that the "product life cycle" for most biotech products is relatively short, somewhat similar to that for "fad" products. What often causes the life of an agricultural biotech product or technology to be short is a patent held by another firm that blocks the development of a product, or the creation of new intellectual property that supersedes the original technology. However, patents can also lengthen the life of a product by blocking the development of competitors (Smith, 2002). The problem for SMEs is that they start at a great disadvantage in trying to build a patent portfolio. One interview respondent commented on the impact of the regulatory process for biotech crops: "It costs between $15 and 20 million to get approval for each biotech event. This would put the marketing of these crops out of the reach of small companies and force us to market through a large company. For many crops, the regulatory requirements are excessive." He observed "it will be much cheaper to get approval for biofuel crops because one does not have to test for possible food allergies." Clearly, the cost of governance of intellectual property is a significant barrier to entry to biotech markets (Chataway, Tait, & Wield, 2006). This barrier would be the target of any policy support efforts if SMEs had their choice.

Global Implications of the Results

Some implications of significance to the global agricultural biotechnology industry can be drawn from the interview data gathered during this study. Two, in particular, involve economic development issues.

First, virtually all small agricultural biotechnology firms owe their existence to university research programs. Although there are a few SMEs derived from governmental biotech research programs, most firms interviewed in this study indicated that their operations are based on intellectual property originally developed in university programs. Also, universities are the source of most scientific staff hired by startups. Thus, it is clear that the future of the agricultural biotechnology industry depends on university programs. This implies that the

industry will grow in relatively wealthy countries with well-funded university research programs, and it will not develop in relatively poor countries that cannot afford such programs. This may add to the rich-versus-poor divide among countries competing in agricultural commodity markets because productivity increases are expected to continue coming from biotech programs, and agricultural producers in wealthy nations will have more access to biotech-enhanced products. Countries unable to afford university research programs may respond to the need for biotech-enhanced products by sending students to foreign universities to gain the expertise and access to the IP necessary to start SMEs upon their return home, but this raises a second problem.

The second major implication for the global industry to come from this study is that large amounts of long-term funding is needed by agricultural biotech startups so, again, only wealthy countries can support such an industry. Even if a poor country is successful in getting its students trained in the scientific skills needed to launch an agricultural biotech firm, the funding necessary for product development is not likely to be available. Interview data collected in this study indicate that millions of dollars are needed over a period of several years to fund the development of a single agricultural biotech product. Thus, SMEs need access to risk capital in amounts usually available only in very liquid capital markets.

Concluding Comments

This study contributes to the discussion of agricultural biotechnology and its future by addressing issues related to the business models being adopted by small firms within the emerging industry. Specifically, two questions were raised: "is there some flaw in the business structure of firms in the industry?" and "is the economic and policy environment facing the industry not conducive to supporting SMEs?" Information gathered using interviews of "insiders" from firms located in several countries provides answers to the questions and insights into the industry's future.

First, it does not appear that there is some flaw in the business structure of firms in the industry. All of the senior managers interviewed were aware of the risky nature of the industry and had some risk-management strategy in place. In almost every case, the largest source of risk facing the firm was funding limits. The firms are structured as science-based product-development operations with some potential IP "in hand" before the firm was created. The risk faced is being able to acquire sufficient funding to cover operating and regulatory costs incurred as the IP is developed and the market for it is accessed. Most startup firms used business models that minimized these costs through partnering or other collaboration efforts until they became self-sufficient in meeting their funding needs through sustainable market activities. This information indicates that the trouble lies in the second question.

It appears clear that the current economic and policy environment facing the industry in all countries is not conducive to supporting SMEs. Interview responses repeatedly pointed out that both the economic environment and the policy environment facing the industry are sources of difficulties for SMEs. Economic factors mentioned centered around the availability of long-term risk capital. Policy factors cited most often include the legal hurdles faced in the regulatory process. A firm in the United States noted the interrelated nature of both types of factors in saying that most investors want their money back with some return in five years or less, but the regulatory process involved in getting an agricultural biotechnology product approved usually lasts seven years.

The single most obvious implication of these results is that large firms will continue to dominate the agricultural biotechnology industry in countries around the globe. The managers of small firms interviewed for this study do not expect any change in that industry structure, even though they offered many examples of how it is small firms that perform most of the innovative science. At present, small firms in this important emerging industry will continue to be what *Investopedia* calls "highly speculative." That uncertain future seems consistent with the responses of SME managers to the interview question, "how do you envision your firm in ten years?" A typical reply was, "there are three paths possible: we are bought out for our intellectual property, we merge into a big firm, or we forward-integrate into becoming a larger firm. The third alternative is most desirable and the goal." The question for policy-makers is "what is the best future for this important industry and will our country be part of it?"

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Author's Notes

This study was funded by the Organization for Economic Cooperation and Development to support work on "Agricultural Biotechnology: Emerging Economic/ Business Models and Institutional Drivers" as part of its multi-year International Futures Project entitled "The Bioeconomy to 2030: Designing a Policy Agenda."