MULTI-DISCIPLINARY ISSUES
INTERNATIONAL FUTURES PROGRAMME

OECD International Futures Project on
"The Bioeconomy to 2030: Designing a Policy Agenda"

Small and Medium Enterprises in Agricultural Biotechnology

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April 2008

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The relatively new agricultural biotechnology industry is attracting much attention from industry and policy-making organizations 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. The source of much of the new technological innovations coming from the agricultural biotechnology industry is small and medium enterprises (SMEs) that are research-intensive in their activities, but very fragile in their existence. In each country where agricultural biotechnology is being developed there are SMEs contributing to the advancement of the science. However, little of the financial rewards from this science seems to be captured by SMEs and, as a result, those firms often fail. The high failure rate of SMEs raises several 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?" Addressing questions such as these is necessary when assessing whether the industry can indeed have the significant impact on agriculture as expected based on its early performance. Therefore, this study contributes to the discussion of agricultural biotechnology by addressing both of these questions.

1. Introduction to the Research Question

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 with a forward looking perspective so as to identify what the agricultural biotechnology industry is expected to be in both the near future and as far out as the year 2030.

1.1. Background on the Industry

The agricultural biotechnology industry is relatively new, but its potential impact on agriculture is great. For example, Falck-Zepeda *et al* (2000) found that an early product of biotechnology research, Bt cotton, generated $240 million in economic benefits when it was introduced in the United States in 1996, with 59% of those benefits going to U.S. 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 *et al*., 2005). With consumer acceptance gradually expanding, the markets for agricultural biotechnology products will offer farmers in wealthy and poor countries economic incentives to switch their production from conventional to biotech products (Hillyer, 1999; Spielman et al, 2006). However, there are significant differences in the rates of consumer acceptance of these products across countries, so many policy issues remain which influence the future of the agricultural biotechnology industry (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 *et al*. 2005; Johnson and Melkonyan, 2003; Joly and Lemarie, 1998; Oehmke and 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. 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 aims 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 and 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 and 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 and Montgomery, 2004) to joint ventures and subcontracting out of specific activities from one firm to another (Chiesa and 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 and 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 *et al*, 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.

1.2. 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; Mangematin *et al* 2001; Chataway, 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 *et al*, 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 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.

2. Method of Analysis

The usual methodology for assessing an established industry is to evaluate its structure, conduct, and performance – in that order. Conversely, to evaluate the relatively new, and still evolving, agricultural biotechnology industry it might be more insightful to reverse the order of analysis.

Traditionally, researchers in the field of industrial organization have begun by studying an industry's structure because structural issues such as the number and relative size of firms in an industry influence the types of conduct exhibited by those firms. Next, it was shown that the type of business conduct observed within an industry influenced the economic performance of the industry. However, in an industry like 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 firms may plan in reverse order to the usual method of analysis: to gain the desired profit performance, some type of business conduct is needed, so the question is what firm structure will facilitate that conduct. In other words, the potential for high levels of profit performance drives agricultural biotechnology firms' 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 (1) identify business models used by SMEs, and (2) evaluate factors that will influence the future of agricultural biotechnology firms and the industry. 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. Therefore, this study uses primary data, rather than data from secondary sources, to accomplish its goals.

3. Method of Data Collection

The best source of information about the business plans and behavior of a firm is the business managers directing that firm. Therefore, telephone interviews were conducted with senior managers of small and medium agricultural biotechnology firms from 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 Organization for Economic Cooperation and Development (OECD) during a lengthy project entitled "The Bioeconomy to 2030: Designing a Policy Agenda." 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. Firms from each category in each stratum in the list were selected by the OECD to be invited to participate in this study. Letters of invitation were e-mailed by the OECD to those firms early in March 2008. As needed, telephone calls were made to follow-up on the invitation letters. Approximately 30 firms were invited to participate in this study. Those firms are located in North America, Europe, South America, and Australia. Once a firm agreed to participate in this study, a senior manager was contacted via e-mail about scheduling a telephone interview.

Each telephone interview was structured by the use of a written questionnaire. That standardized document assured that each question was read by the interviewer to the interviewee in identical terms across interviews. That method of structuring the interviews was designed to reduce bias in the responses received. The hard-copy questionnaire form was also used to record all responses and notes during the interview. Using a structured questionnaire facilitated efficient movement from one question to another. The result was that the entire interview, consisting of 30 questions (mostly open-ended), usually required only 30-40 minutes. The longest interviews lasted nearly an hour because the interviewer encouraged respondents to offer all ideas on many of the points addressed.

4. Interview Results

A total of 18 interviews were conducted during March and April 2008. That translates into a total response rate of over 50 percent for the firms that were sent an invitation to participate. Information was collected from firms located in the United States, Canada, Germany, Denmark, France, and Australia.

The responses of all firms to each question are summarized in the Appendix at the end of this report. The format of the Appendix shows the questions that were asked and the responses tallied. The question numbers in the Appendix show the order in which the questions were asked. For questions asked in "yes/no" and multiple-choice formats, the number of responses in each answer category is presented. For open-ended questions, the appendix presents notes summarizing the comments made, with each respondent's comments presented as a separate line (or paragraph) of text. The order of the lines is maintained across each question, so it is often possible for readers to see what a single respondent's replies were to each question. However, not all respondents made comments on every question.

4.1. Characteristics of Firms in the Study

The agricultural biotechnology firms included in this study are all research oriented in their activities. To get some understanding of the nature of the scientific methods being used, each firm was asked to identify all of the procedures they used. As shown in the Appendix (question 5), 89% of firms indicated that they used genetic modification, 78% used marker-assisted selection methods, 22% used cisgenesis, 17% used gene shuffling, and 22% also used some other procedure. Every firm used either genetic modification or marker-assisted selection, and two-thirds of all firms used both of those methods.

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.[1] As shown in Table 1 (constructed from the responses to questions 8-11), the total value of business assets, total revenues per year, and the research and development portion of each firm's annual budget vary significantly. To get a perspective of the typical firm interviewed, readers should use the "median" response, reported in the last column on the right side of Table 1. It shows that SMEs are typically operating with about US$27 million worth of assets, yet they are currently generating only about US$3-4 million in annual revenues. That gives an asset turnover ratio of about 0.13:1, which is very low.[2] 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.

[1] A nineteenth firm was interviewed to augment the data collected from SMEs. The nineteenth firm is a cooperative of consultants that advise SMEs, but it is not a SME itself. Thus, no data from that firm is reported in the tables and other statistics in this report; only comments from the firm are used to help express issues.
[2] A basic asset turnover ratio is calculated as 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.

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)	16.9	103	0	3
Total revenue expected in 2008 (US $M)	19.5	120	0	4.4
Percent of total budget in R&D	69.3	100	5	72.5
Number of employees	40.5	249	3	23

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 to question 7 in the Appendix show that 83% of the firms in the sample are focusing mostly on product development, rather than on marketing of products, with 17% having about equal focus in their 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, and if the market accepts the product, the last stage of a small or medium firm's evolution is to expand its product line to expand its profit margin. 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 respond to question 7 by indicating that its focus was more on marketing of products, even though it may still have a significant product development effort underway.

Most of the firms interviewed indicated that they are using a "portfolio" approach to product development. The fact that 72% of firms answered question 6 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 1-4. To begin, responses to questions 1-3 are 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 56% 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 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 flows 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 39% of the SMEs interviewed sell services to custumers. 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, 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. 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) intellectual property, but without sufficient capital or market access, may choose to license that property to another firm which will 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 intellectual property 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 35% in 2008. This is consistent with the hypothesis that firms would prefer to capture all of the market value of their intellectual property 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 for one or more products.

Table 2 - Summary of Responses to Revenue Source Questions

	Percent of "yes" responses
Do you produce and/or market products?	56
Does your firm sell services?	39
Does your firm license its technology to other firms?	78

Firms that answered "yes" to question 1, indicating that they are deriving revenue from product markets, were asked to identify the types of product(s) they had. The responses are summarized in Table 3. As indicated earlier, firms did have a portfolio approach to agricultural biotech markets: nearly every firm receiving revenues from products had more than one type of product, with most firms having products in two or three of the five types listed in the table.

Table 3 - Summary of Responses to Product Types Question

Does firm produce/market this type of product:	*Percent of firms*
Food	70
Animal feed	40
Industrial feedstocks	30
Biofuels	30
Other	60

Table 4 - Summary of Responses to Market Segment Question

Does the market for your products include:	*Percent of "yes" responses*
Agriculture	100
Animal breeding	11
Forestry	22
Aquaculture	11
Health	33
Other	22

Table 4 shows that the SMEs interviewed all served the agricultural market segment of the biotechnology market, but most also served other segments. Only 33% of the firms were in the agricultural market segment only. This is another indication of the portfolio approach to spreading the risks associated with being in the biotech market. Some of the respondents indicated that this was a natural result of being able to leverage their intellectual property, while others said it was an intentional risk management strategy.

Table 5 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 what percentage of the entire sample of firms interviewed participate in the segment. Of those firms participating in the segment listed at the top of the column, the share of those which also participate in one of the other two market segments is presented in the second through fourth rows. The bottom row of Table 5 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, 39% 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, with a unique industry structure. In other words, in other 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.

Table 5 - Cross-Participation in Segments of the Biotech Industry

	Food	*Biofuels*	*Health*
Percent of total firms surveyed	39	17	33
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.

4.2. Industry Size, Competition, and Composition

The dynamic nature of the global agricultural biotechnology industry makes it virtually impossible to keep track of how many firms are involved. Therefore, interviewees were asked to offer their estimate of the number of firms in their country and how many domestic and foreign competitors they faced in the market. This "insider" information serves two purposes. First, it gives some indication of the scale of the industry, both by country and in total. Second, the variability of responses is an indicator of the volatility of the industry's evolution. Table 6 presents the data (composed of responses to questions 12-14).

Table 6 - Summary of Responses to Industry Size and Competition Questions

How many:	*Average*	*Highest*	*Lowest*	*Median*
Biotech firms in the U.S.	221.4	800	20	50
Biotech firms in Canada	52.5	100	5	52.5
Biotech firms in France	47.3	80	12	50
Biotech firms in Germany	390	390	390	390
Biotech firms in Denmark	300	300	300	300
Biotech firms in Australia	3	3	3	3
Direct domestic competitors	5.9	25	0	3
Foreign competitors	37.3	500	0	7.5

Table 6 is clear in its message: the industry is quite volatile but substantial in its size. The fact that there is a wide range between the highest and lowest estimates of the number of firms within a country – especially in the United States which had the largest sample of firms interviewed – shows that senior managers in the industry are not able to easily keep tabs on their competition. Part of the reason for that is the high number of firms involved in each country except Australia, where there are only a few biotech SMEs. Using the median response for each country still shows that the piece of the industry occupied by SMEs, versus large firms, is dynamic and competitive in nature. Whereas, an industry made up of only a few large firms is considered an "oligopoly" in its structure and imperfectly competitive in its behavior, the agricultural biotechnology industry appears to be "monopolistically competitive" in its structure and behavior. However, this observation needs additional research attention because the agricultural biotech industry is unique in its composition that includes a few very large firms and many small firms with few firms of intermediate size.

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. The median response to question 13 indicates that SMEs believe that only a handful of domestic firms compete with them. Similarly, the median response to question 14 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-U.S. 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.

The diversified nature of SMEs in agricultural biotechnology results in very little difference in responses between firms with products in different market segments. As shown in Table 7, questions about the number of domestic and foreign competitors got similar responses from firms in three of the largest market segments: food, biofuels, and health (pharmaceuticals). As noted earlier when discussing the results in Table 5, the high degree of cross-participation in segments of the biotechnology market blurs distinctions between firms in one segment versus another segment. Therefore, no clear conclusions can be drawn from the data in Table 7 about the presence of unique structural aspects of any market segment. For example, it could be hypothesized that SMEs in the health (pharmaceutical) market segment would expect to have more competitors because, in general, there are more pharmaceutical biotech firms in the world than there are firms in the biofuels segment.

However, *agricultural* biotechnology firms appear to be so much more diversified across market segments than are non-agricultural biotech firms that this hypothesis may not hold. Even though the median response to the "number of direct competitors" question is "10" for firms in the health segment and only "5" for biofuels firms, the number of observations in this study is too low to accept the hypothesis with much confidence – even though the results here are consistent with the hypothesis.

Table 7 - Summary of Responses to Industry Competition Questions, by Segment

	Food	*Biofuels*	*Health*
How many direct competitors: Median	3	5	10
How many direct competitors: Highest	25	20	25
How many direct competitors: Lowest	0	5	0
How many foreign competitors: Median	8	8	5
How many foreign competitors: Highest	10	10	10
How many foreign competitors: Lowest	0	5	3

4.3. 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 (in question 15), "do university biotechnology programs aid or hinder the market?" Fifteen of the eighteen 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 start-up 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.

In question 16, respondents were asked directly, "what factors have caused a change in business opportunities for agricultural SMEs in the past?" Table 8 shows that many factors were identified by most firms. The response most common from 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 have effects on 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 is causing them to subcontract out research to SMEs. Large firms are trying to reduce fixed and variable costs and that means have fewer people, which shifts the research agenda of large firms."

Table 8 - Summary of Responses to Business Opportunities Question

Has this factor caused a change in business opportunities for SMEs:	*Percent of "yes" responses*
Industry concentration	61
Firm size growth	22
Cost of applying biotechnologies	67
Change in profit margins	28
Change in competitive advantage compared to large firms	28
Patents	61
Collaboration opportunities with larger firms	44
Other	50

When asked whether conditions affecting business opportunities are different for animal breeding and forestry firms (question 17), respondents were split with 67% saying "yes." Comments from people believing there are differences were enlightening. One person noted that "forestry firms face barriers to entry from the cost of R&D and the long-term payback period." Another person said the "animal breeding biotech industry is influenced by feedstock fluctuations. The regulatory environment is getting tighter, not easier." A third person tried to sum it up: "each industry is unique. Forestry is easier than food, due to differences in public perspective on the products. Yet, forestry is harder than food, due to its long-term return on investment horizon. Animal breeding is harder than agriculture."

Question 18 followed up by asking "what role do you believe SMEs play in the development of biotechnologies aimed at animal health or propagation?" Most responses were typical of this one: "similar to agricultural firms: they have collaborations in research and marketing, and they perform tasks outsourced by large firms." Another comment offered more details: "the scientific input is very valuable from SMEs and large companies are hesitant to take on new technologies. So, the large firms are focusing on marketing, etc., of products often developed by SMEs."

4.4. Business Opportunities for Firms in the Industry

A series of interview questions addressed issues influencing the business environment and opportunities facing small and medium enterprise in the agricultural biotechnology industry in particular. To begin, respondents were asked (question 22) "do technical factors provide specific competitive disadvantages for SMEs?" The responses were 72% "yes." There appears to be a positive relationship between a firm's revenues and the chances of it answering "yes" to this question. There was a positive correlation ($r = 0.38$) between responses to the two questions, with firms having higher revenues more likely to think SMEs faced competitive disadvantages due to technical factors. The two themes in comments from people answering "yes" were patents and costs. One person observed that "technical factors affect everyone, small and large. Patents, however, are a disadvantage to SMEs because the large firms have the resources to patent everything and fund lengthy litigation." Another person said "patents block access to technology." As explained by one person, "intellectual property and patents are becoming more complex and pervasive, while their costs rise. Regulatory maneuverability in getting to the product stage is getting more difficult. Public acceptance issues cause regulatory costs to be higher than necessary." Finally, one person complained that "regulatory costs up to US$50 million per event are very constraining." The thinking of the minority of people answering "no" is captured in the comment from one person: "technology moves fast, so SMEs can 'work around' technical factors. Patents were more important long ago, but they have eased in the quality of protection they provide, thus reducing their power to create technical barriers to competitors."

The next question (#23) sought to identify what stage of business evolution each firm interviewed was at. The question was "which is more important to a SME's survival, access to elite germplasm or access to market outlets for a firm's products?" It is expected that firms in the earliest stage of business evolution would focus on the science issues involved in developing a product, whereas firms farther into their evolution would turn their attention to market development issues. About 31% of respondents answered "germplasm," while about 69% said "market outlets." Interestingly, there is a inverse relationship between a firm's revenues and the chances of it answering "market outlets" to this question. The negative correlation between responses to the two questions indicates that firms with higher revenues are less likely to think that market outlets are more important to a SME's survival than is access to elite germplasm. In other words, all but one of the firms with sales revenues of US$5 million or less are more likely to think access to market outlets is most important, while firms with sales revenues of US$12 million or more coming from markets are more likely to think access to germplasm is key to survival. This result seems to be explained by the comment that "if you have access to elite germplasm and develop a product, there will be a market for it. Conversely, market access for a poor product from inferior germplasm will not lead to success." However, the market segment targeted by a firm appears to be an important factor, as implied in this comment: "without a marketing plan, a business will fail. Germplasm is important only for a food product, not non-food products." So, product quality is important in establishing a firm's business opportunities, but those opportunities must be carefully pursued in the competitive markets for agricultural biotech products. One respondent summed up the debate this way: "ultimately, success is determined by whether consumers want the product." In summary, firms not yet established in a product market think that market access is most important to their survival, but once firms do establish themselves, they think product quality, derived from elite germplasm, is more important to their survival.

The many comments about the very high costs of developing an agricultural biotech product may lead someone to expect that small and medium enterprises would benefit from and, therefore, seek out cooperative efforts in conducting research. So, question 24 asked "what roles have research cooperatives played in SME development?" The responses showed a clear difference between North American firms and firms in Europe. In North America, there was little experience with research cooperatives and, as a result, little evidence that they had played any role in the industry's development. In Europe the experience was completely different, with firms expressing strong support for the idea that cooperatives were a significant player in that industry. One European firm said "without cooperatives SMEs would be almost non-existent." Another European comment described the role of cooperatives by saying "generally this is very positive because it allows companies to gain resources in areas where they are not specialized. It also keeps them up to date with the latest research in academia which is very important as it is a low cost input."

Given the geographical differences in the responses to the previous question, it is understandable that similar differences appeared in responses to the follow up question (#25), "are research cooperatives a viable strategy for SMEs to remain independent?" About 56% of the total sample of firms interviewed answered "no" to this question, but responses varied across locations. All European firms replied "yes", while all Canadian and Australian firms answered "no" and 75% of U.S. firms also said "no." The views of the minority of firms in support of this strategy are summed up by this comment: "a cooperative can provide access to technical information that enables a SME to create a product." The majority of firms had little exposure to research cooperatives, thus had little faith in them as a business opportunity.

Many respondents did have faith in business opportunities coming from the advantages they saw in small and medium enterprises. This was apparent in the responses to question 26: "what do you see as the advantages and disadvantages of SMEs compared to large firms?" Two themes came out in responses about the advantages of SMEs: the efficiency of operations, and flexibility in research focus. SMEs see opportunities to identify and serve market niches because small firms can "move quicker because they have fewer layers in decision-making." One person said "SMEs are more nimble in getting things done and changing direction. SMEs are braver in going into new patent areas," while another person added "SMEs have the ability to move quickly in response to the market. They are more flexible in their research focus." Part of the explanation for SMEs' ability to respond quickly to the market is that they are willing to take more risks than large firms, yet SMEs are better able to manage their risk exposure through their "greater willingness to collaborate." Also, it was observed that "small firms will serve a market niche that big firms will ignore as being not profitable enough."

Business opportunities are constrained by the disadvantages of SMEs. The most obvious and serious disadvantage faced by SMEs is a shortage of funds. When a biotech firm is first organized it has a negative cash flow, referred to as its "burn rate," because research expenses are high and no incoming revenue will be available until the firm has some product or services to sell. This influences the business strategies SMEs can use. One interview respondent said his firm had to use a "shorter term strategy because of their search for money. There are a lot of resources that are needed which cannot be held in house (lawyers, regulatory filing, marketing, etc.)." Another respondent made a similar point: "MSEs suffer from diseconomies of scale. SMEs do not have the regulatory and legal resources needed, sometimes causing them to pass up good opportunities." This is a significant problem because "product development is a 7-year process" and, in the end, a "lack of market opportunities mean SMEs must use large firms to reach the market."

Ultimately, all firms are in pursuit of business opportunities that will lead them to achieving the goal of the firm. Therefore, knowing what goals are held by firms operating within the agricultural biotechnology industry would signal what types of business opportunities are seen as available in the industry. Hence, interviewees were asked (question 28) "what is the goal of your firm?" Of course, nearly all responses included some reference to earning profits for the firm's shareholders, but several other goals were mentioned that offer insights into what business opportunities these SMEs believe can be achieved in the industry. A sample of those goals follows: "to have a high impact on agricultural product markets, reduce the cost of food, and improve farmer profitability;" "to be a pharmaceutical developer partnered with a large firm;" "generate knowledge and tools (i.e. products) for a competitive agricultural sector that is respectful of the environment;" and "change the fundamental way energy is produced."

The amount of control a firm believes it has in achieving its goals is reflected in its approach to pricing its products. In the monopolistically competitive type of industry structure apparent in agricultural biotechnology, firms are expected to have some control over the pricing of their products. However, in the interview responses, a clear range of control is seen, from little to significant amounts of control being exercised by firms. In response to the question (#29), "what factors affect the prices your firm charges for its products?", interviewees showed little market power in some market segments where product differentiation between firms is relatively modest. For example, a bio-energy firm answered "pricing of energy biotech is driven by commodity and fuel prices." Conversely, a high degree of market power is apparent in this response from a firm with a high degree of differentiation in its products compared to the products of competitors, "what the market will bear." In general, firms' responses were typified by this reply from a firm adding value to agricultural seeds, "commodity prices, benefits to farmers from saving seed, and the utility of the trait added by our biotechnology."

Finally, the degree of success a firm expects to have in pursuing the business opportunities available to it is reflected its answer to the question (#30), "how do you envision your firm in ten years?" The possibilities for SMEs were laid out by one respondent: "There are three paths possible: they are bought out for their intellectual property, they merge into a big firm, or they forward-integrate into becoming a larger … firm. The third alternative is most desirable and the goal." Responses of nearly all other firms were consistent with one of three paths laid out. Nevertheless, in every case, firms expected to be successful in raising the wealth of their owners/investors. Therefore, the real goal of SMEs appears to be to develop some product and/or technology that has sufficient market value to attract the attention of a larger firm so as to lead to some type of consolidation of the two firms.

4.5. 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 will be done in section 5 of this report. 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 (question 19) "in your experience, what types of business models are SMEs currently using?" It quickly became clear that most respondents were uncertain of the meaning of the term "business model," so their answers focused on the business strategies and general business behavior of their firm. Nevertheless, 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 below.

4.5.1. Technology Suppliers

Comments from several respondents showed that their firm was still early in its evolution and 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."

4.5.2. 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, "they 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 R&D costs and accessing additional human and financial resources were often cited as reasons for using this strategy.

4.5.3. 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 that 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."

4.5.4. Blended Models

One respondent described that 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 section 4.E-1 and 4.E-2 above with the result including a risk spreading component, such as that described in section 4.E-3. 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.

4.5.5. 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 indicates the weak bargaining position of SMEs caused by their financial constraints.

4.5.6. Factors Making Business Models Evolve

Interview respondents were asked (question 20) "what economic, technical, or social factors are likely to make these models evolve in the future?" Answers tended to focus on two issues: factors external to the firm, and business strategies.

External factors expected to be drivers of evolution in SME business models were varied. Several interviewees mentioned consumer acceptance of GM food. For example, one person said, "more countries will accept bio-crops, thus expanding the market" because "the cost of food is increasing." Another related factor mentioned was "a new wave of product traits will create change." Part of that change may come from the "expiration of intellectual property" that was protected by patents from early years of biotechnology. Another respondent added that "technology is becoming standardized and more available globally. Social drivers: climate change, global development both create opportunities. Scale economies continue to drive intellectual property and regulatory issues, especially regarding the cost of those activities." Finally, someone observed that "business conditions are key: recession slows the level of research being done due to the effects of reduced funding on R&D budgets. Biotech is a worldwide business, and SMEs with customers in diverse locations and in diverse markets are more likely to survive."

Several respondents made comments about firms' business strategies and the need to adjust them to conditions within the agricultural biotechnology industry. One example was that "business models need to separate the functions of value-capture and planting," meaning that firms need to understand who will benefit from the traits added to a product by the intellectual property. The business environment itself received attention, such as this comment: "cost and risks involved, especially political/legal and access to funding" will change, so "alliances will grow in importance." Another person agreed, saying the "potential for collaboration with large firms" is a key strategy because it offers "access to brainpower." However, a respondent added "licensing will stay," but warned that "joint ventures are based on infrastructure, so they need credit available." In other words, access to financial resources is always going to be a major constraint when SMEs select their business models.

4.5.7. Successful Business Models of the Future

The final question (#21) about business models used by SMEs generated surprising results. The question was "what types of business models are likely to be successful in the future, even up to 2030?" The surprise was that little change is expected by firms interviewed. The general mood is characterized by the response "there will be no change soon because large firms are very dominant." That opinion was seconded by another respondent: "No real changes are likely in the market system for agricultural biotech. The 3-5 biggest firms will remain dominant." However, some improvement is possible, in the opinions of several respondents, for individual firms in some types of biotech product markets. This perspective is illustrated by the comment, "businesses that have the ability to develop new 'value added' products that will differentiate that firm from competitors" can grow because "technology products are becoming commodities, needing differentiation to justify price premiums. Firms using plants to create industrial products and/or nutritionally enhanced food products" have bright prospects.

In general, agreement was apparent on a few points. First, "partnerships are key. SMEs cannot go alone due to financial constraints." "Start-ups will have to sell their technology because they have to satisfy their investors. The investors want a major return as soon as possible." A second point of agreement is that SMEs must "fit into a place in the channel, not try to do everything. They must be niche players." This idea was elaborated on by another respondent, "vertical integration is good, but horizontal integration is better. It spreads risks across markets."

Putting all comments on this question together leads to the conclusion reached by one interviewee. That person said “all current SME models can be successful, but being a technical supplier is the most likely role for SMEs.”

4.6. Policy Reasons to Support SMEs

The discussion of small and medium enterprises and their business models reported thus far clearly demonstrates that the industry is dynamic and may have some structural characteristics that might be used to justify government intervention. Therefore, the SME managers interviewed were asked whether they wanted to see policy actions on behalf of their industry. The question (#27) was “are there policy reasons to support SMEs so they continue to play an active role in agricultural biotechnology? Surprisingly, only 75% answered “yes,” including all firms from Canada, all but one from Europe, and most from the United States. Those answering “no” are from the United States, Australia, and a single European firm. The reasons they gave for wanting no policy support are apparent in the comment “government inefficiency may hinder the industry,” with another theme being that “regulations add problems.”

The large majority that favored having policy support for their industry provided arguments falling into three categories: structural issues, competitive market development, and efficiency issues. Those arguments are summarized in the subsections below.

4.6.1. Structural issues

One comment captured the usual arguments in support of government intervention in cases where monopoly power might exist within an industry.

> “Concentration has created a polarity with very large and very small firms, and the large firm’s economic position is such that they can buy whoever they like. The lack of medium firms creates a situation where society is dependent on a very small number of very large firms to distribute products and they can make mistakes and not follow an optimal technology development pattern.”

A second comment provides a supporting argument usually presented in the cases of emerging markets. That comment, “no firms are big when they start, so the industry needs to have a chance for growth,” helps show how the first problem of industry concentration can lead to large firms dominating the market. There is a risk that the few large firms can “kill off” small firms before they can grow into a competitor, thus large firms can maintain their dominance in the market. In emerging markets – those with many new and weak firms – government intervention to protect the small firms is usually justified by the idea that the entire market might fail unless protected. In the case of agricultural biotechnology, the industry structure is a hybrid: a mix of an oligopoly of a few large and stable firms, and an emerging market of small, weak firms that are new and at risk of failure. In such an unusual industry structure, it is likely that the large firms would use their superior market power to eliminate any small firms that might become a competitive threat.

4.6.2. Competitive market development

The unique structural issues noted above lead directly to arguments for policy support so as to create and develop a competitive market for biotech products. Respondent comments of this sort argue that policy support for SMEs in agricultural biotechnology industries are necessary to “foster economic growth” and “to maintain competition in markets” because “SMEs are valuable conduits that help get university technology into markets." One person noted that SMEs "are a training ground for new scientists." Other respondents suggest that SMEs expand "the diversity in science that is conducted." This helps "foster competition, resulting in lower costs to consumers. With more firms, there is higher product penetration." For example, "having SMEs preserves a smaller scale in the seed industry."

4.6.3 Efficiency Issues

Several respondents argued that from increased competition comes increased efficiency in the operations of individual firms. Specifically, one person said "SMEs are efficient." A second comment added "the innovation of SMEs speed breakthroughs in science that are needed by society." The result is that "with SMEs in a market more products are developed because there are fewer restrictions on research priorities." However, it was pointed out that "scale economies issues need to be addressed, protecting SMEs so that their research is done. Many new, good technological innovations come from SMEs, not large firms." In summary, a respondent concluded that "SMEs are indispensable to the development of technology."

5. Business Models and Their Implications for Agricultural Biotechnology

The interview results reported for this study have considerable results enabling 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.

5.1. 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 start-ups, 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 Start-ups – Start-ups are high risk-reward attempts to capture some intellectual property (IP) that has value to other (usually larger) firms that can develop a market for some product that includes the IP from the start-up 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 start-ups:

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

Most new agricultural biotechnology firms begin as a high-risk start-up. 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 being dictated by its level of funding raising. The source of failure of this category of firm is almost always insufficient funding.

A low-risk start-up 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, 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 technology 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 up from start-up 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.

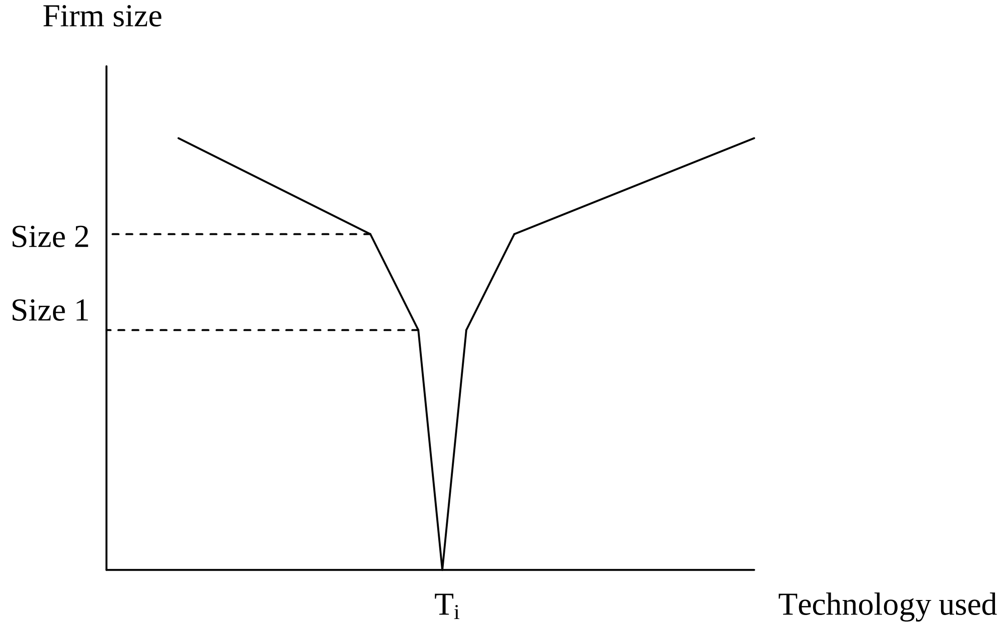
A horizontally integrated SME still may be involved in only a narrow range of activities or technologies, but they have expanded their market access by applying those technologies to a wider range of products. This business model reduces the market risk exposure of the firm by diversifying into different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

As firms evolve and progress through the different categories of business models outlined above, they display the behavior illustrated in Figure 1. That behavior demonstrates the relationship between a firm's size and the range of technologies used by the firm (the technologies used are those along the horizontal axis in the range between the two lines at the point representing the firm's size). As shown in the stylized figure, agricultural biotechnology firms smaller than size 1 focus their activities on the use of a narrow range of technologies centering on some principal technology (called T_i in the figure). This behavior generally fits the business models of start-ups and specialized SMEs. When a firm grows to Size 1, it can afford to expand its range of technologies used (shown in the Figure as a wider horizontal range between the two lines at the level of the dashed line extending from the firm size labeled “Size 1”). This is what happens when a firm adopts a horizontally integrated business model. Vertical integration may also lead to using additional technologies. Finally, when a firm grows to some larger size (such as Size 2 in Figure 1), it may adopt both horizontal and vertical integration strategies which greatly expands the range of technologies used within the firm.[3]

Figure 1 - The Relationship Between Firm Size and Range of Technologies Used



The behavior outlined in the relationship illustrated in Figure 1 is consistent with the “blended models” described in sub-section 4.E-4. The three models outlined in that sub-section are also consistent with the progression of SMEs through the business models observed by most of the respondents to the interviews conducted during this study.

5.2. 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. This issue is a prime target for policy action to support SMEs, from the perspective of economic development.

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

[3] Note that the horizontal distance between the two lines in Figure 1 grows with firm size. At firm sizes 1 and 2 the rate at which the horizontal distance expands becomes higher.

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 which 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 *et al*, 2006). This barrier would be the target of any policy support efforts, if SMEs had their choice.

5.3. The Key Question: Can SMEs Succeed on Their Own?

The key economic question facing small and medium enterprises in agricultural biotechnology industries in countries around the world is "can SMEs succeed on their own?" The complete question can be stated as: "are SMEs able to develop GM crop varieties themselves and bring them to market, or are they mostly forced to follow a licensing business model in which they license gene technology to large seed firms?" The information collected in this interview study provides answers to each piece of the complete question.

To begin, the first piece of the question is "are SMEs able to develop genetically modified crop varieties themselves"? The general answer is "yes," as evidenced by the success of SMEs in each country. Information from senior managers of SMEs contacted for this study consistently indicate that biotech start-up firms are begun only when someone has an established piece of intellectual property (IP) on which to base a value-adding business. However, the IP is not always the result of research work completed by the person involved in the SME – universities are very often the source of the original research – so, strictly speaking, SMEs are not all able to develop GM crop varieties themselves. This indicates the critical link between university biotech programs and the size and structure of the agricultural biotechnology industry in most countries. In countries without such university programs, government research programs are the only other possible source for the IP upon which SMEs can build a commercial firm.

The second piece of the complete question is "are SMEs able to bring GM crop varieties to the market themselves?" The answer to this question appears to be "only in rare cases." Nearly all interview responses indicate that most SMEs lack two essential inputs for a successful marketing effort: money and market infrastructure. The cost of getting an agricultural biotech product approved for market entry is staggering and, therefore, usually far more than many SMEs can raise. Furthermore, even if a SME can raise the amount of money necessary for market entry, and they are able to hire people with market expertise, the firm will usually not have the infrastructure needed to access a market. This hurdle was evident in the fact that firms with annual revenues of US$5 million or less all replied that market access was more important to their success than was access to elite germplasm. The key pieces of a successful market infrastructure are contacts with a customer base and a delivery system in place that links the firm to its customers. These pieces take time and effort to develop, so SMEs are disadvantaged without them.

The answers above to the first two pieces of the total question lead to an obvious answer for the last piece of that question: "are SMEs mostly forced to follow a licensing business model in which they license gene technology to large seed firms?" The answer is "yes" in nearly every case. However, that is not the end of the story for SMEs. Most senior managers interviewed understood the need for their firm to use a licensing business model until their firm grew large enough to be self-sufficient in biotech product markets. Yet, some of those managers said their firm planned to pursue that growth to become medium-to-large in size so that it could remain independent.

6. References

Altman, I., P. Klein, and T. Johnson, "Scale and Transaction Costs in the U.S. Biopower Industry," *Journal of Agricultural and Food Industrial Organization* 5, 1 (2007): Article 10.

Begemann, Brett D., "Competitive Strategies of Biotechnology Firms: Implications for U.S. Agriculture," *Journal of Agricultural and Applied Economics* 29, 1 (1997): 117-122.

Brennan, M., C. Pray, A. Naseem, and J. Oehmke, "An Innovation Market Approach to Analyzing Impacts of Mergers and Acquisitions in the Plant Biotechnology Industry," *AgBioForum* 8, 2-3 (2005): 89-99.

Chataway, Joanna, "Novartis: New Agribusiness Strategy," AgBioForum 4, 1 (2001): 14-19.

Chataway, J., J. Tait, and D. Wield, "The Governance of Agro- and Pharmaceutical Biotechnology Innovation: Public Policy and Industrial Strategy," *Technology Analysis and Strategic Management* 18, 2 (2006): 169-185.

Chiesa, V. and G. Toletti, "Network of Collaborations for Innovation: The Case of Biotechnology," *Technology Analysis and Strategic Management* 16, 1 (2004): 73-96.

Falck-Zepeda, J., G. Traxler, and R. Nelson, "Surplus Distribution from the Introduction of a Biotechnology Innovation," *American Journal of Agricultural Economics* 82, 2 (2000): 360-369.

Fulton, M., and K. Giannakas, "Agricultural Biotechnology and Industry Structure," *AgBioForum* 4, 2 (2001): 137-151.

Giannakas, K., and A. Yiannaka, "Market and Welfare Effects of Second-Generation, Consumer-Oriented GM Products," *American Journal of Agricultural Economics* 90, 1 (2008): 152-171.

Hillyer, Gregg, "Biotechnology Offers U.S. Farmers Promises and Problems," *AgBioForum* 2, 2 (1999): 99-102.

Horsch, R. and J. Montgomery, "Why We Partner: Collaborations Between the Private and Public Sectors for Food Security and Poverty Alleviation Through Agricultural Biotechnology," *AgBioForum* 7, 1-2 (2004): 80-83.

Johnson, S. and T. Melkonyan, "Strategic Behavior and Consolidation in the Agricultural Biotechnology Industry," *American Journal of Agricultural Economics* 85, 1 (2003): 216-233.

Joly, P-B., and S. Lemarie, "Industry Consolidation, Public Attitude and the Future of Plant Biotechnology in Europe," *AgBioForum* 1, 2 (1998): 85-90.

Kalaitzandonakes, N. and B. Bjornson, "Vertical and Horizontal Coordination in the Agro-Biotechnology Industry: Evidence and Implications," *Journal of Agricultural and Applied Economics* 29, 1 (1997): 129-139.

Lockie, S., G. Lawrence, K. Lyons, and J. Grice, "Factors Underlying Support or Opposition to Biotechnology Among Australian Food Consumers and Implications for Retailer-Led Food Regulation," *Food Policy* 30, 4 (2005): 399-418.

Mangematin, V., S. Lemarie, and D. Catherine, "French Ag-Biotech SMEs: Development Prospects," *AgBioForum* 4, 2 (2001): 98-104.

Marco, A. and G. Rausser, “The Role of Patent Rights in Mergers: Consolidation in Plant Biotechnology,” *American Journal of Agricultural Economics* 90, 1 (2008): 133-151.

Oehmke, J. and C. Wolf, “Measuring Concentration in the Biotechnology R&D Industry: Adjusting for Interfirm Transfer of Genetic Materials,” *AgBioForum* 6, 3 (2003): 134-140.

Sheldon, Ian M., “Regulation of Biotechnology: Will We Ever ‘Freely’ Trade GMOs?,” *European Review of Agricultural Economics* 29, 1 (2002): 155-176.

Smith, Pamela J., “Patent Rights and Trade: Analysis of Biological Products, Medicinals and Botanicals, and Pharmaceuticals,” *American Journal of Agricultural Economics* 84, 2 (2002): 495-512.

Spielman, D., J. Cohen, and P. Zambrano, “Will Agbiotech-Applications Reach Marginalized Farmers? Evidence from Developing Countries,” *AgBioForum* 9, 1 (2006): 23-30.

Traill, B., and C. Duffield, “The Structure of the European Agro-Food Biotechnology Industry: Are Strategic Alliances Here to Stay?” in Santaniello, V., R. Evenson, and D. Zilberman (eds.), *Market Development for Genetically Modified Foods*, Wallingford, U.K. and New York: CABI, 2002, pp 283-290.

Wilson, W., B. Dahl and B. Maxwell, “Grower Response to Contracts and Risk in Genetically Modified (GM) Crops,” *Journal of Agricultural and Resource Economics* 32, 1 (2007): 135-153.

APPENDIX: Summary of Interview Responses

1. Does your firm produce and/or market products? Yes _10_ No _8_ If so, what types?

7 food
4 animal feed
3 industrial feedstocks
3 biofuels
7 other: livestock forage, industrial and pharmaceuticals, veterinary, pharmaceutical, inputs to forestry, soil remediation, plant varieties

2. Does your firm sell services? Yes _7_ No _11_ If so, what are they?

7 - contract research services
1 – market feasibility studies

3. Does your firm license its technology to other firms? Yes _14_ No _4_

4. Does the market for your products include (check all that apply)

18 agriculture
2 animal breeding
4 forestry
2 aquaculture
6 health
3 other: veterinary, energy, soil remediation

5. Does your firm use (check all that apply)
16 genetic modification (GM)
14 marker-assisted selection (MAS)
4 cisgenesis
3 gene shuffling
4 other biotechnologies: research tailored for customer's need, antibody libraries, bioinformatics especially for genomic information and transcriptome analysis, mutagenesis – chemical and radiation

6. Does your firm have (or seek to develop) a "portfolio" of products _13_ or do you specialize in one or a few products _5_? (check one box)

7. Is your firm's focus more on

15 product development
0 marketing of products
3 equal focus

8. What percentage of your firm's total budget was accounted for by *research and development* (R&D) last year? _________ %

65%, 70 %, 5% of sales, 70%, 80%, 100%, 70%, 50%, 75%, 100%, 80%, 35-40%, 5%, 95%, 100%, 12.5%, 100%

9. What was your firm's total revenue last year? [All answers are expressed in US$] (NA = no answer)

$0, $40M, NA, $0 ($2M in capital investment), $1M, $2M, 0, $10k, $5M, $23M, $4M, $20M, $60M, 0, 0, $103M, $12M

10. What do you expect your total revenue to be this year? [All answers are expressed in US$] (NA = no answer)

$0, $40m+, NA, $0, $1M, $2.1M, 0, $10k+, $6.7M, $23M, $15M, $25-30M, $65, 0, 0, $120M, $12M

11. Approximately what is the value of your firm's total assets? [All answers are expressed in US$] (NA = no answer)

$30M, $24M, NA, $12M, $15M, $1.5M, $23M, $70M, $200M, $180M, $36M, NA, $38M, $6M, NA, NA, NA

12. How many biotechnology firms are there in your country? (? = did not know/guess)

U.S. = ?, 100s, 500, 800, 30, 20, 50, 50+
Canada = 5, 100
Germany = 390
France = 80, 50, 12
Denmark = 100-500
Australia = very few, NA

13. How many of those firms do you consider to be direct competitors?

U.S. = 6-8, 20, 15, 25, 0, 5, 10-12, <5
Canada = 0, 1
Germany = 3
France = 0, 0, 3
Denmark = 0
Australia = 0, 0

14. How many foreign firms compete with you? ________________

U.S. = 0, 10, 5, 3, 3, 5-10, 500, <5
Canada = 8-10, 4
Germany = 15
France = 10, 10, 8
Denmark = 0
Australia = 7, NA

15. Do university biotechnology programs aid or hinder the market? Aid _15_ Hinder _2_ Please explain.

Aid:
Many biotech firms come from universities, thus expanding the industry.
Universities provide the basic research for the benefit of the industry, provided that they do not act like a private enterprise.
Universities do advanced research.

Universities are technology developers, the basis for start-up firms.
Genetic tools come from universities.
Any research helps agriculture and universities are big contributors.
They rely on data from basic research and this is provided by universities. They cannot do that research because they are working on product development.
Their firm is a university spin-off. Commercial ideas often come from university programs.
The more technology that is developed, the better it is for the market.
Their firm is a university spin-off. They have a relationship with two universities.
Universities do basic research that commercial firms cannot afford to do. Universities do development work. Universities provide third-party credibility.
There isn't a direct benefit in terms of developing a new variety, but in terms of technology proving and scientific information.
Universities often share competencies (academics sit on their scientific advisory board), knowledge, and physical assets (lab space and equipment) with SMEs.
There has been a large rationalization of publicly funded agricultural research.

Hinder:
Universities' market direction can be convoluted.
There are almost no more university programs in France for agricultural biotechnology. There is not one university lab with an agronomic program, and perhaps 3 labs within the government. The mentality is very destructive and very fixed on regulatory issues, not on bringing products to the market. They were the last hold outs conducting field trials in France, but they have had so many problems that this year they will move all trials to the US. In 22 years he has worked in this field and they used to always work with the public sector…since 5 years there is no more interlocutors in the public sector…they used to be respected as scientists but now the young scientists know nothing but destruction of field trials. In France there used to be a real expertise but this is drying up and moving away.

16. What factors have caused a change in business opportunities for agricultural SMEs in the past? (check all that apply)

11 Industry concentration (mergers and acquisitions)
4 Firm size growth (in average sales and/or number of products)
12 Cost of applying biotechnologies
5 Change in profit margins
5 Change in competitive advantage compared to large firms
11 Patents
8 Collaboration opportunities with larger firms
10 other comments:

Yield in crops, water supplies.
New science creates new opportunities.
Patents add to market stability.
Less funding for SMEs; less collaboration in some technology areas; fewer acquisitions compared to the pharmaceutical industry.
Market access to desirable traits in products.
Economics of large firms is causing them to subcontract out research to SMEs. Large firms are trying to reduce fixed and variable costs and that means have fewer people, which shifts the research agenda of large firms.
Regulatory environment is very strict and has lengthened timelines and raised costs
Regulatory hurdles have increased.
The speed of technological advances is increasing. Cost is $35-40M to develop and market a product.

Anti-GM push aids in the concentration of the industry because only large firms can withstand many protests.
Commodity prices create business opportunities.
Large firms have a big scale advantage.

17. Are conditions different for animal breeding and forestry firms? Yes _8_ No _4_
If yes, how?

They are free from big firm competition.
They are more restricted.
Forestry firms face barriers to entry from the cost of R&D and the long-term payback period.
Conditions are similar. At least $1.5M in depreciable assets is needed to begin operations.
Each industry is unique. Forestry is easier than food, due to differences in public perspective on the products. Yet, forestry is harder than food, due to its long-term ROI horizon. Animal breeding is harder than agriculture.
Animal breeding biotech industry is influenced by feedstock fluctuations. The regulatory environment is getting tighter, not easier.
There are longer time lines in forestry.
The conditions are radically different because of the major industrial infrastructure requirements involved in animals and forestry. There is an equivalent in potatoes with freeze drying (*e.g.* French fries and chips – McCain & Frito Lay) but this is not as important as in forestry or animals.
He feels that there is a major difference because trees take a long time to prepare for the market whereas animals have a very quick growth time.

18. What role do you believe SMEs play in the development of biotechnologies aimed at animal health or propagation?

They improve forage quality, improving animal health.
Similar to agricultural firms: they have collaborations in research and marketing, and they perform tasks outsourced by large firms.
The same role as SMEs in agricultural biotech.
SMEs generate the new technology, not big firms.
The scientific input is very valuable from SMEs and large companies are hesitant to take on new technologies. So, the large firms are focusing on marketing, etc., of products often developed by SMEs.
Big role. SMEs and large firms face the same issues, but SMEs contribute innovation.
Big role; maybe bigger role than played by large firms because of SMEs' willingness to undertake some types of research.
SMEs can act as a link between public research and the market.
That depends greatly on the product…they generally produce high value, not high volume, products.
SMEs can be/are the most innovative and SMEs should unify their efforts to increase research capacity, this is required because today there is almost a monopoly on animal health.

19. In your experience, what types of business models are SMEs currently using?

They focus on technology to sell to other firms for marketing.
They form strategic alliances with tech partners, thus enabling specialization. Outsourcing is used widely. They learn to "dance with the titans".
They focus on development of R&D (rather than doing basic R&D) or on marketing of R&D. They are niche players.
SMEs are often trying to develop technology that can be sold to a large firm.

They develop exclusive licenses, few bring GM products to market. Some SMEs do joint R&D to reduce cost.

This 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.

There are innovative companies that perform R&D and they look to develop to proof of concept and then try to sell or license to large companies. But in animal breeding it is difficult to convince large companies until the technology advances very near to market approval. So these small companies are always looking for cash to take the technology further down the development chain. So in animals it is difficult to be an innovative small company. This isn't the case for companies (not very innovative) which take products proven on humans and transfer them to veterinary. He compared this to generics.

SMEs are opportunistic in collaborating/partnering with large firms. SMEs have little vertical integration.

An agricultural SME and a mid-sized seed firm are very different. 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.

Partnership is really one of the only ones that exist at present. It is essential.

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 other firm that can do the marketing of product developed from IP, and (3) use plan #1 blended with slowly doing more product development on their own – "self-developed".

SMEs are trending toward being a technical supplier to bigger firms. More partnerships are being seen. There is no standard model for SME success.

They specialize in the development of niche technologies. There are some that work on export, but this is generally through licenses rather than actual product delivery. Cooperation isn't as important for R&D in the potato sector, but they are developing with [another firm] a variety that can make a good frozen french-fry.

Primarily, SMEs act as suppliers of technology and services to larger firms. In many ways they also act as a supplier of human resources.

To exist in the future SMEs must become fully integrated: HR, research, marketing, etc. This could be achieved through collaboration, but if they remain dependent on large firms it is a recipe for failure.

The firm has a gene suite, derived from plants, that improves pest resistance. The goal is to license the suite, which includes markers and boosters, to a major seed firm, who will insert the gene suite into elite germplasm.

Their main business model, as a publicly funded organization, is to provide a benefit for [their country]. They are required to develop new varieties for crop species where there is market failure, or significant adverse conditions that are not being adequately dealt with by private sector firms. An example is citrus, where [their country's] international competitiveness is under threat from producers in South America. They have worked on developing new products with improved quality traits, such as sweeter, easier to peel etc. Their focus here is to develop traits with export appeal. They develop new varieties that are ready for commercialization, but they are not involved in marketing themselves. They usually license their varieties to SMEs, rarely to large seed firms. The licenses are usually taken up by collaboratives. For example, in fruit, half a dozen nurseries in a region will create a consortium and take out a license. These consortiums rarely conduct further breeding work, but they will come back to [the firm] with ideas from their customers on what needs to be improved.

20. What economic, technical, or social factors are likely to make these models evolve in the future?

More countries will accept bio-crops, thus expanding the market. Cost of food is increasing. Biofuels have big potential.

Cost and risks involved, especially political/legal and access to funding. Alliances will grow in importance.

Potential for collaboration with large firms. Access to "brainpower."

A new wave of product traits will create change. Expiration of intellectual property. Consumer acceptance of GM food.

European consumer acceptance of GM food increases. Regulatory hurdles will be lowered. Increasing interest in specific-trait markets.

Business conditions are key: recession slows the level of research being done due to the effects of reduced funding on R&D budgets. Biotech is a worldwide business, and SMEs with customers in diverse locations and in diverse markets are more likely to survive.

Economic factors: market growth for veterinary products will drive increases in revenues. Also sometimes government action (e.g. phasing out antibiotic use for animals in the EU) will create opportunities for firms to provide alternatives. Similar logic applies to fears about infectious diseases. Social: increased meat consumption creates a much larger market. At the same time, to meet demand, developing countries are developing more industrial food processing, which raises concerns about animal health. Economic growth is making these models more viable. Technical: more targeted medications for specific genomes will create opportunities for SMEs.

Some SMEs will go public, if the trading environment is better.

Business models need to separate the functions of value-capture and planting. A carbon credit system is needed to capture all of the benefits of biotech. Anti-GM pressure will decrease.

Principle of precaution in France is killing the industry. The risk management bar is placed so high that discoveries cannot be transformed into products without major capital. France has not evolved in his 22 years of research. After his first internship in the public sector, he wanted to go to a private firm where he could turn research into real products, but there were none. He was given the impression that people were not interested in the private sector being involved. Since then, he has a great relation with the public research sector, but they do not want products, just research and publications.

Licensing will stay. Joint ventures are based on infrastructure, so they need credit available. Ag biotech (for energy products) is counter-cyclical to the general economy.

Technology is becoming standardized and more available globally. Social drivers: climate change, global development both create opportunities. Scale economies continue to drive intellectual property and regulatory issues, especially regarding the cost of those activities.

Economic - Because of budgets and patents there are obstacles to SMEs having genetic resources. This is a reason to avoid patents in variety production and use instead POVs like in Europe. It takes 10 years for a new potato variety which leads to concentration and costs about 20 million to develop a new potato variety. This means 30 years are required for a suitable return on investment. This makes finding investors very difficult. **Societal -** Since people consume potatoes directly, the use of GM is too close to direct consumer consumption. Anti-GM sentiment becomes like a religious belief that you cannot argue with, so "even if you find a good gene and develop a good variety, it is like trying to sell pork in Saudi Arabia."

The good flow of people from one industry to the other has a fertilizing effect on biotech. People can set up companies because short term (startup) capital is relatively easy to get allowing them to try out new business models. Long term capital is the challenge. Without a shift in business models in large firms, bureaucracy will continue hindering innovation. This will continue to provide opportunities for SMEs to push forward innovative ideas as a result of small communication lines and the ability to take risks. It is a mutually beneficial relationship.

The main problem in Australia is the state based moratoriums on GM crops. This will hopefully change due to a change in public perceptions. There is a much greater awareness of drought problems among the Australian public, due to the severity of the last drought which brought drought conditions into the cities for the first time. Also, agricultural inputs such as fertilizers are large producers of Greenhouse gases (GHG). New crop varieties that could reduce such inputs and deal with drought and other stresses should change public attitudes to GM.

If there continues to be a small number of SMEs, without major organizational efforts, it will be difficult for these firms to have a sufficient return on investment. Access to the market will remain incredibly important.

Increasing concentration for GM technology is a major concern. At this rate, we expect only 3 major players in the market: Monsanto, the Chinese Government, and one other large firm, perhaps Dupont-Syngenta (they already have an alliance for agbio). Bayer Crop Science might still remain an active player. This could create problems for SMEs, since their business model is based on licensing genes to a major. If there are only two or three, the majors will have a buyers market for new technology.

Funding models are coming under pressure – they are supposed to cover more of their costs through licensing. In terms of technical factors, their breeding is increasingly focused on improving resource efficiency use, such as for water and nutrients. They are very concerned in [their country] about phosphate, since the global supply of rock phosphate will probably be used up in 40 to 70 years and soils [in their country] are phosphate poor. They need to improve the efficiency with which [their country's] crops can extract phosphate from these soils.

21. What types of business models are likely to be successful in the future, even up to 2030?

No change soon because large firms are very dominant. SMEs may be bought by big firms.

Collaboration among groups and firms (www.PIPRA.org is an example).

Fit into a place in the channel, not try to do everything. Niche players.

Businesses that have the ability to develop new "value added" products that will differentiate that firm from competitors. Technology products are becoming commodities, needing differentiation to justify price premiums. Firms using plants to create industrial products and/or nutritionally enhanced food products.

No real changes are likely in the market system for agricultural biotech. The 3-5 biggest firms will remain dominant.

Vertical integration is good, but horizontal integration is better. It spreads risks across markets.

Existing business models will not be successful because the companies are always strapped for cash. The best thing would be to create a consortium with academics, small companies (product development), and marketing elements. This already occurs, but needs to start much earlier in the development process than it does now. It should also focus on developing a specific product.

Partnerships are key. SMEs cannot go alone due to financial constraints.

Little change will occur in the next 20 years, just fewer firms will exist. The limited number of multi-national firms will control markets and there will be a small number of science-based SMEs.

Start-ups will have to sell their technology because they have to satisfy their investors. The investors want a major return as soon as possible. He doesn't see a major role for SMEs without major structural changes.

Energy firms have big potential. Business model that is a long-term winner is to blend the development of IP for licensing to bigger firms with slowly doing more product development on their own – "self-developed".

All current SME models can be successful, but being a technical supplier is the most likely role for SMEs.

The vision needs to be aimed at developing varieties that have a culinary advantage (at least in

Europe) or that are adapted to specific climate conditions (to increase yields) and regional tastes. For SMEs, a variety that is well known for quality will be very important, especially for potatoes and vegetables. For export, SMEs cannot have a strategy based on large volumes because this is going to be difficult to sustainable.

Collaboration with large firms will continue to be a key. They need each other.

Develop a strategy to be fully integrated (through cooperation) with other SMEs to remain independent and viable. In agriculture, the MNC business model is not going to remain viable in the long term due to the need for competition.

The rise in prices for agricultural commodities is likely to stay for some time, although possibly not at current levels. More attractive profits should increase the supply of VC for agricultural biotech, particularly for biofuels. SMEs could make some headway in this field, particularly for cellulosic based biofuels, because the majors do not have the elite germplasm locked up. There are still business opportunities for SMEs in switchgrasses and other cellulosic biomass. This could be very profitable, particularly if cellulosic processes could produce butanol.

I think VC has largely ignored agbio because 1) commodity prices were very low, so the profit margins were also low, 2) it takes about 12 to 15 years to bring a product to market, which is even slower than in health biotech applications.

One area where agbio SMEs face better market conditions is in specialty markets such as pharmaceuticals or other fine chemicals, where access to elite germplasm is not necessary.

Will change, but no idea how.

22. Do technical factors provide specific competitive disadvantages for SMEs? Yes _13_ No _5_ Examples: if they are unable to insert genes for valuable traits into a variety of crops?
If patents held by large firms either block research or increase research costs?

Yes:

Monsanto patent blocks them. Patents were too broad early on.

Patents block access to technology.

Regulatory costs up to $50M per event are very constraining.

SMEs face capacity-related constraints. SMEs' breadth of patents gained has narrowed.

SMEs have a hard time due to high development costs.

Intellectual property and patents are becoming more complex and pervasive, while their costs rise. Regulatory maneuverability in getting to the product stage is getting more difficult. Public acceptance issues cause regulatory costs to be higher than necessary.

If a company can control a specific market (*e.g.* EU or American) then they will control genes and technical factors will be problematic. Competition is required.

Cost of meeting regulatory requirements is a problem for SMEs.

No:

Technology moves fast, so SMEs can "work around" technical factors. Patents were more important long ago, but they have eased in the quality of protection they provide, thus reducing their power to create technical barriers to competitors.

Technical factors affect everyone, small and large. Patents, however, are a disadvantage to SMEs because the large firms have the resources to patent everything and fund lengthy litigation.

SMEs will always find their niches where they can survive and where the technical challenges cited above won't be a problem.

23. Which is more important to a SME's survival? (check one box)

_5_ access to elite germplasm

_11_ access to market outlets for a firm's products
Please explain.

Often go together. For biofuels, germplasm is more important.
Depends on the mission statement of the firm, it could be either.
Germplasm is the basis of a SME's existence.
Without a marketing plan, a business will fail. Germplasm is important only for a food product, not non-food products.
Germplasm is important if selling seeds, but SMEs will not usually be in product sales. SMEs have a unique product, not lots of products.
Market share and a marketing plan are everything. The market drives the direction of research.
Ultimately, success is determined by whether consumers want the product.
Access to germplasm is very expensive and proprietary.
Access to germplasm is major driver in the validation process. A market will be there when a product is developed.
If you have access to elite germplasm and develop a product, there will be a market for it. Conversely, market access for a poor product from inferior germplasm will not lead to success.
When a market is open to competition, germplasm can be licensed.
SMEs will never be able to afford access to elite germplasm for major crop varieties, which means that the only possible business model is to license genes to the major seed firms. Our goal is to earn royalties on future seed sales by one of them. We are currently jointly developing our technology in a collaboration with a major. SMEs such as our firm also can't afford the regulatory costs. This means that we have to collaborate with a major to be able to get our product to the market.

24. What role have research cooperatives played in SME development?

Government labs and universities have helped SMEs.
Not sure.
Very little.
Resource sharing is key for SMEs.
Coops have offered funding at the right time in a SME's efforts to complete product development. However, coops can move in the wrong direction for the market.
Coops played a giant role early on, but are now not very efficient.
Generally this is very positive because it allows companies to gain resources in areas where they are not specialized. It also keeps them up to date with the latest research in academia which is very important as it is a low cost input. But this needs to occur at an earlier stage to be effective.
Not much.
Research coops have played a substantial role in the development of SMEs, but little has come of it.
Without cooperatives SMEs would be almost non-existent. For example, without cooperatives there wouldn't have been the Geno plante project in France.
Not much seen in small firms. In the energy sector some collaboration is very important.
Very little.
Not sure that there is a large distinction between the two because often the models are merged. Many of these were set up as private companies with farmers as the shareholders. Cooperative research (in France, especially with the government) is an advantage in the same way that universities are by giving access to knowledge that otherwise isn't available. This isn't, however, decisive.
This hasn't played a major role for them despite being in a cluster with 900 employees in 90 IT and biotech firms. The arrangement is really just on paper and not utilized.
At present they have played a very small role, but this needs to be developed for the future.

25. Are research cooperatives a viable strategy for SMEs to remain independent? Yes _7_ No _9_
Please explain.

Yes:

A cooperative can provide access to technical information that enables a SME to create a product.

Cooperatives help only in upstream activities, not downstream activities. Few firms know product development.

It is not always beneficial for SMEs to remain independent because the investors need to be paid. This could work however if the goal was to remain independent because the access to data and research could allow enough innovation that investors could be found.

He is not sure that this will actually be sufficient. There is no real viable alternative however.

This is the same role as played by the universities, and can also aid in the protection of patents for SMEs.

Yes, but it comes down to resources at the end. It is a good way to conserve resources but there are many organizational challenges. It is like a networking group, they sound like a good idea but not many people get anything out of it because it isn't seen as a priority. This should be prioritized more.

This is a viable strategy as SMEs will need to support one another to remain independent and viable, however serious effort needs to be put into developing a research strategy.

Almost all of their research is collaborative, but SMEs are mostly involved at the development end.

No:

Cooperatives do not have the same motivation. The Return On Investment is lower.

Cooperatives help find the direction of the market.

Research cooperatives are obsolete now.

Research cooperatives can play a minor role.

No – not in terms of a publicly funded research cooperative such as […]. All […] research is done at universities, with 130 researchers funded by […]. The main focus is on identifying genes, including boosters and promoters, that provide tolerance to abiotic stress, including frost, drought, salinity, boron, etc; and identifying markers linked to these genes.

[…]'s goal is to develop improved varieties of wheat and barley for Australian farmers. Traditionally, public research organizations in Australia developed new varieties. There was a clear market failure, so public money was needed to create public benefits. An example is the Flagship Barley variety, which was developed by the University of Adelaide right through to commercial release. A university or public cooperative such as […] can't do this for GM varieties because of the regulation costs and because of the cost of crossing genes into lead varieties.

Small firms simply can't afford the costs of developing improved GM wheat or barley for the Australian market, due to high development and regulatory costs. A global market is needed, and few if any Australian seed firms serve such a market.

A possible funding source in Australia is the Australian Wheat Board and the Australian Barley Board, but neither has shown interest.

Consequently, our business model is based on licensing gene technology to one of the majors: Monsanto, Pioneer, Syngenta, Bayer Crop Science, Limagrain, etc. We currently have a good collaborative relationship with [a large firm]. […] identifies abiotic stress genes and take these as far as the first round of field trials (proof of function). The agreement is that [the large firm] has the rights to use these genes in corn and other hybrid crops, but […] has the rights over the use of these genes for wheat and barley. Let's assume that [the large firm] is able to introduce one of our patented genes for drought tolerance into a corn variety. We will then earn royalties on this gene that can help fund our work, and we will get data that will help reduce Australian regulatory costs for the use of the gene in wheat or barley. We could then develop wheat or barley varieties to the commercial stage, but we still aren't clear how we will do this.

A major block for […] is that we cannot afford the costs of meeting regulatory requirements for GM. Our total annual research budget is about 10 million AUD (excluding overhead costs, which are provided in-kind). The total regulatory cost for a GM wheat or barley variety in Australia is about 15 to 20 million dollars (Monsanto claims the cost is about 50 million, but we don't believe this). However, the regulatory cost will drop an order of magnitude to about 1.5 to 2 million dollars if the same gene is approved for use in the US, for instance in a corn variety. We could then use this information to reduce Australian regulatory costs. Our agreement with [the large firm] is that they will provide us their regulatory data if they use one of our genes in a crop such as corn, for example for the US market.

The regulatory cost for a non GM variety in Australia is zero. There are also no regulatory costs for markers that can be used in conventional breeding. For GM, we need toxicology data etc. Cisgenesis in Australia is regulated as for GM, so we can't use this route. An example is boron tolerance, which is a serious problem in Australia because of high levels of boron in the soils. The Flagship Barley developed by the university of Adelaide is intolerant of boron, but the genes that give the good attributes for Flagship Barley are right next to the genes that increase boron intolerance. We can't get rid of this intolerance without using GM. We could do this through cisgenesis, but the regulatory situation blocks this option.

We are generally OK with the Federal regulations for GM – the system is rigorous but science based. The testing requirements are a good thing, both for public safety and to ensure public acceptance. GM crops are far better tested for safety than any other type of crop. Our problem is the state moratoriums on GM.

26. What do you see as the advantages and disadvantages of SMEs compared to large firms?
Advantages:

Efficiency of SMEs in accomplishing a joint effort across sciences within a firm.
Efficiency. SMEs move quicker because they have fewer layers in decision-making.
SMEs have more efficiencies, including better focus/direction and shorter timeframes.
SMEs have less administration. SMEs are able to focus, which is a freedom.
SMEs are more nimble in getting things done and changing direction. SMEs are braver in going into new patent areas.
SMEs have the ability to move quickly in response to the market. They are more flexible in their research focus.
Flexibility because you are not tied to market creation. Close links with university.
Speed of execution. Better focus. Partnering is easier.
Quicker decision-making. Greater innovation. More risk-taking.
There are none.
SMEs can try truly innovative ideas. SMEs can quickly develop ideas.
Specialization and focus are possible in SMEs. SMEs are faster, more nimble in getting things done. SMEs have greater willingness to collaborate. Small firms will serve a market niche that big firms will ignore as being not profitable enough.

Since research is very close to commercialization and marketing, R&D is aimed truly at developing products and can be much more reactive to changing market conditions. Since they are small the dialogue between the researchers and the marketers are close.

Ability to be focused, small communication lines, little bureaucracy.

None at the moment. A crucial problem is with venture capital (VC). VC looks for an exit after 5 to 7 years, whereas the timeline for developing a GM variety, after the genes have been identified, is about 8 years. You need to be a long way down the development path in agriculture before you get interest. The mechanism is much more established in health, where the models for funding drug development are well developed and fully understood. For example, if you tell a VC firm that you have a drug that will improve breast cancer survival by 50% and that it has passed Phase I trials the VC firm can immediately calculate the risks, the probability that the product will reach the market, etc. There are clear pathways, timelines, known survival rates for new products, and a full understanding of the risks and potential market sizes. VC firms do not have this information for agricultural products. We now have a 'proof of function' stage, based on the results of the first field trials, but there are no data on success rates or other milestones. We need a well defined 'pathway' for agbio before VC is likely to express much interest. There are very few small agbio firms that can take a gene discovery right through to the market. Those that do find something of interest are usually bought out by one of the majors. One of the problems for small agbio firms, and for ourselves, is how to work out the royalties for gene IP when genes are increasingly stacked. Monsanto's latest product has 8 genes. How will you determine royalties if a stack includes genes for herbicide tolerance, pest resistance, promoters, boosters, and possibly a [firm's name] gene for salt tolerance? Which ones are creating value, and how much?

Reactivity and proximity to the market. Niche markets. Human resources.

Disadvantages:

Funding constraints. Must control "burn rate" because increasing rates require increasing funds.

Dealing with costs and risks. SMEs need to focus on maximizing resource use. Less ability to leverage brainpower. Less political clout, legal staff.

Lack of capital and resources.

Lack of infrastructure and resources.

Failure rate often due to funding shortage.

SMEs have restrictions on their growth due to funding limits.

Shorter term strategy because of search for money. There are a lot of resources that are needed which cannot be held in house (lawyers, regulatory filing, marketing, etc.). Also, the company is vulnerable because knowledge is often held with only a few people, so the companies are very dependent on those few people.

Lack of financial resources. Lack of market experience. Need to partner to complete big trials.

Funding: difficulty in securing long-term capital (product development is a 7-year process). Lack of market opportunities – SMEs must use large firms to reach the market.

They are always looking for money.

Less funding and expertise is available. SMEs can lack depth or breadth in expertise. Some projects are more expensive for a SME.

MSEs suffer from diseconomies of scale. SMEs do not have the regulatory and legal resources needed, sometimes causing them to pass up good opportunities.

Access to financing! Their financial situation excludes the development of major long term research program and has an impact on marketing, because they cannot afford large publicity campaigns. He recognized that this isn't always a benefit however as demonstrated by public backlash against Monsanto.

Lack of long term money and the fear of losing focus because of lack of resources. As an SME, you have to wear a lot of different hats and as a result it is difficult to avoid being distracted.

Many!

Financing! French banks are no longer interested in funding companies, they only want to make money with money. Outside of France this appears to be less problematic.

An SME cannot afford the regulatory costs, which are about 50 million USD for a new GM variety, plus we can't afford or have access to the hundreds of different elite germplasms that are necessary. It would be possible to enter into a smaller market, such as horticultural products, but we are not sure if any of these markets are large enough to recoup development costs.

27. Are there policy reasons to support SMEs so they continue to play an active role in agricultural biotechnology? Yes _12_ No _4_ Please explain.

Yes:

SMEs are efficient. They are a training ground for new scientists. With SMEs in a market more products are developed because there are fewer restrictions on research priorities.

To maintain competition in markets. The diversity in science that is conducted. To facilitate doing gene discovery and mapping.

To foster economic growth. To maintain competition in markets. SMEs are valuable conduits that help get university technology into markets.

Good ideas come from universities and SMEs. SMEs are indispensable to the development of technology.

Concentration has created a polarity with very large and very small firms, and the large firm's economic position is such that they can buy whoever they like. The lack of medium firms, creates a situation where society is dependent on a very small number of very large firms to distribute products and they can make mistakes and not follow an optimal technology development pattern.

No firms are big when they start, so the industry needs to have a chance for growth.

SMEs foster competition, resulting in lower costs to consumers. With more firms, there is higher product penetration. Having SMEs preserves smaller scale in the seed industry.

Young scientists with initiative need a creative outlet that they will not receive in a large firm. Today no young scientists are coming into this area and, without action, the resource pool will continue to dry up. Young scientists need to be able to see results from their actions and they need to see that these actions are serving their home country, not someone else. Today, the quality of research in university is good but there is no application or transfer to industry.

The innovation of SMEs speed breakthroughs in science that are needed by society.

Scale economies issues need to be addressed, protecting SMEs so that their research is done. Many new, good technological innovations come from SMEs, not large firms.

SMEs are important to large firms because without them the level of innovation being delivered would suffer.

SMEs aid agricultural R&D considerably but the government is not taking notice because they do not have large market capitalization and revenues. Encouragement can be given by giving access to financing so that SMEs have a better cash flow and can continue conducting R&D. The government could also encourage grouping in research consortiums.

No:

Government inefficiency may hinder the industry.

Regulations add problems.
There are a lot of political reasons not to invest in biotechnology, especially in GM since the two are associated in the public mind.
There simply isn't a large enough market in Australia to support agbio SMEs, given the development costs.

28. What is the goal of your firm?

Happy shareholders. To generate higher returns than do big firms. To aid the world.
To create value through innovation.
To research, develop, and market small grains. Make money. Advance biotech.
To make a profit and a return to investors.
To have a high impact on agricultural product markets, reduce the cost of food, and improve farmer profitability.
To generate a profit for investors.
Bring a technology to the market so that they become independent of external funding for R&D. This would allow for continuing R&D and a stream of innovative technology development. There is no preference for total independence from external firms in terms of marketing, etc., (although if it worked why not). R&D independence could be achieved through licensing, etc.
To be a pharmaceutical developer partnered with a large firm.
Profit for shareholders by creating products that make more profit due to their wide consumer acceptance. Reduce the carbon footprint of agriculture.
Generate knowledge and tools (i.e. products) for a competitive agricultural sector that is respectful of the environment.
Change the fundamental way energy is produced.
Maximize returns to investors through biotech product sales, and aid the world's food and fiber supply.
Develop varieties that come from their R&D. Up until now, 95% of their money comes from their own protected varieties. They do have a few licenses but this tends to be a much less important part of their business.
To contribute to soil and water remediation.
When […] was established about 5 years ago, the business strategy was fairly hard nosed. The idea was to develop IP and earn revenues from licensing it. We have shifted to more of a public good business model. We don't give out IP for free (except for markers), but we don't expect to earn much money from our IP within Australia. We currently have 21 patent applications. Our revenue model is largely based on earning money from overseas. […] is established as a firm and it has stockholders, which are all universities. The amount of stock held by any university is exactly equal to the amount of money they provide for research. Every year we increase the stock to match the last year's funding. This insulates […] from the problem of funders that expect to be able to exert control. Although the research is done in many different universities, all IP is owned by […]. One of our problems is that we are active in wheat and barley, which are crops that don't attract much interest from large seed firms, at least for GM. As farmers (in Australia) can keep seed, there isn't much of a market.
1) Keep employees employed (250 employees and the farmers that depend on them). 2) Make a profitable business to give shareholders a sufficient ROI. 3) Develop rural communities in France.

29. What factors affect the prices your firm charges for its products?

The benefits farmers receive from increased yield from our product. Other products.
Gross margin targets. Cost of goods. What the market will bear.

Commodity prices. Benefits to farmers from saving seed. The utility of the trait added by our biotechnology.
What the market will bear. Competitor prices.
Competitors' prices. The benefits to farmers.
Fixed and variable costs. The firm's budget and its need for profits.
Animal products are produced under a very stringent price structure (to bring a pig to slaughter costs X, a cow costs Y) and the firm's products have to fit under that umbrella. This means that technologies that are very expensive per animal treated will never be adopted.
Regulatory hurdles. Overall technology research and development input costs.
Access to risk capital (more capital gives a longer perspective on pricing). Uniqueness of the firm's technology. Overall attitudes/climate toward GM products.
They do not set a price for their services; they do what they can with the money that they are given by their investors (mostly small investors) to pay for the research.
Pricing of energy biotech is driven by commodity and fuel prices.
Technical performance of the product demonstrated to consumers. The direction of customer motivations. Product's competitive position. The time value of money (cash flows).
The return of revenue for the farmers is the major factor. They have to set a price which allows the farmer to get a return that is competitive with a hectare of wheat. Although less important, the strength of the Euro is also important. In Cuba, for example, they compete with Canadians and therefore the Euro is a factor. The price of research is not a major factor in the pricing of their products as they have been able to contain research costs.
It is not based on development of production or development price; it is based on the value of use as compared with its competition. So if their product could save several hundred person-days required to sweep a field for mines, it would be worth a lot.
Competition with MNCs is the main factor. MNCs are ready to fight for a market monopoly so that they can charge anything they like.
They charge a royalty on the sale of initial plant material, then a percentage share of the value of the harvested product. The royalties on the initial plant are low (for instance for citrus trees) but they charge a royalty of about 3% to 5% of the harvest for the life of the plant breeders right (PBR). They also do this using trademarks, particularly for export markets. This is better because the royalties last longer, since a trademark lasts longer than PBRs. Trademarks are often bundled. They have a trademark for mandarins, but several varieties, with different harvest dates, are under the same trademark. In some cases they do not take out a PBR at all. For instance, Singapore is a big market but they use a trademark to protect their IP rather than a PBR. The trademark is also cheaper, as they don't need to prove DUS, etc. License costs depend on the market segment and not the type of licensee. For instance, they charge higher license fees for the use of their RNAi technology for corn or soybeans than for a small market crop.

30. How do you envision your firm in ten years?

Successful, mid-sized (if we are not bought by a big firm).
Two times as big due to product development.
Very prosperous, more efficient.
To become a supplier to a pharmaceutical firm.
Licensing products to other firms.
Much larger and more efficient. The work is getting more sophisticated over time, so the firm needs to grow to have adequate resources to be able to deal with market demands for its services. The market's size is stable, so the firm expects to increase its share of the regional market.
The company goal was to have a product on the market by 2012 and shortly thereafter be profitable. This would allow R&D to develop a pipeline.
Larger and partnering with two pharmaceutical firms doing drug development and manufacturing.

To go public with a minority share of the company.

He doesn't suspect that they will exist independently in 10 years. He assumes that they will be integrated into a larger firm.

There are three paths possible: they are bought out for their intellectual property, they merge into a big firm, or they forward-integrate into becoming a larger energy firm. The third alternative is most desirable and the goal.

To be the premier technical source for their product. Being a productivity leader. Being an industry and public leader on sustainability issues.

It is expected that the market will be stable. While they may have a few additional stakeholders, they are likely to either remain an independent (SME) or they will buy up a competitor. They will also develop their presence in the industrial production side. They also see increasing the collection of royalties through licensing agreements in countries where transport costs or tariffs are too high as an important source of growth.

They will be a fully integrated company using biotech to remediate soils and water (mostly heavy metals) all over the world. They expect to be profitable, with a market value of at least 100 million USD.

1. We hope to have some of our technologies in commercial varieties. 2. We would also like the big majors to return to Australia, since they could probably help develop these varieties. 3. We hope to earn some royalty income from the use of our IP in corn. 4. We would like to see a mechanism in place in Australia to pay for new technology – we need a viable value capture system. Currently farmgate royalties are too small, at only about 1 to 2 dollars per ton, compared to about 40 to 50 dollars per ton for GM varieties in the US. 5. Agriculture is an international industry. We need to embrace international scale and expertise.

If the people in the company remain happy and motivated, they will continue to remain independent and grow.

They don't think it is likely that private firms in [they country] will develop enough to take over the breeding activities of [their firm]. This is because the markets are often too small. Growers also have a mandatory fee that they have to pay on output, which is matched by Government funds. Private firms would not be able to compete with this model. [Their firm's] charter is to work for the benefit of [their country], so they don't breed material for external markets. They do license genes abroad and use this money to subsidize their work, but they also license genes to private firms [in their country] who are then responsible for exporting the technology.