Competition, Regulation, and Intellectual Property Management in Genetically Modified Foods: Evidence from Survey Data

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Abstract

We present survey results regarding a series of hypotheses on industry structure, regulation and patent policy towards GM food crops, focussing on the stages of the industry that generate innovations and approved products for sale to the farming sector. Licensing as a means of delegating litigation and regulatory costs comes out as one of the most consistent themes in our responses. We link this practice to a two-tiered industry structure, a weak relation between litigation threat and research trajectory, and a perception by our respondents that patents – as well as patent design -- are “one step removed” from their research decisions.

Introduction

Genetically Modified ("GM") food represents a unique opportunity to trace a new technology from its inception. It thereby provides a rich example within which we can examine the management of a new technology, as well as public policy towards new technologies. This paper presents a series of hypotheses regarding industry structure, regulation, and patent policy towards GM food crops. We have designed and implemented a survey focussing on the innovations that contribute towards the production of new GM plant varieties to allow us to gather information on the plausibility of these hypotheses. This paper summarises the support (or lack of support) we found for them in our responses.

While our sample size is small, a number of suggestive findings emerge. First, we investigate the competitive structure of GM food. The industry involves a long vertical chain, moving from innovations to approved crops, to cultivation, processing, distribution and finally retail. We investigate the structure of the first two stages of this chain. We find some support for our hypothesis that GM food is perceived, at these stages, as a separate industry from the traditional food sector. This suggests that the relatively high concentration ratios measured GM food are reflective of the true concentration level of this industry. Further, they are well over the levels that generally trigger antitrust scrutiny. Second, for rapidly changing or new markets, it has been suggested that "innovation market" structure be evaluated as a prospective measure of product market structure. We use the survey's support for patents as a measure of market power to propose and evaluate weighted patent counts as an implementation of the innovation market concept. We find that this implementation tends to undervalue patents that are very important in our market so that the prospective measure of market share tends to understate actual levels of concentration, quite drastically in the case of highly important patents.

As we move from patent portfolios to products that are actually approved for commercialisation, we expect to see higher concentration. After all, this is a new industry and product approvals take time. Indeed, we postulate that regulatory approval could have a concentrating influence on this industry by erecting a

significant and persistent entry barrier. Our survey responses lend general support to this hypothesis. In fact, entities owning patents in this area appear to use licensing to delegate regulatory costs. We suggest that a two tier structure of this industry results, with "design" firms providing technology on license to larger "hub" firms that concentrate patents, obtain regulatory approval and manufacture. More stringent GM regulations are likely to increase this concentration. In fact, responses indicate that most of the entry barrier is not due to learning economies, as the regulatory burden is not reported to fall greatly as entities accumulate submissions. This, in turn, indicates that the concentrating influence of regulation is likely to be a long term phenomenon in this field.

Third, we investigate whether patents actually elicit research in this area through their reward function as is, indeed, the presumption of most economic models of the patent system. Patents and their associated revenues are not cited as the primary cause that the *specific* research into GM food has taken place in our sample, even for entities that continue to be active in this field. Indeed, our respondents indicated that other incentives generated their research in this area. On the face of it, this would suggest that strengthening patent protection would be unlikely to generate more research spending by the "reward" route. However respondents also cite that, whatever the reason that was cited for the research to have taken place patents are revenue generators, indicating that patents do fulfil, somewhat, the function of raising the returns to research-based firms. Additionally, our respondents indicate that patents do appear to be viewed as valuable "defensive" tools for raising the cost of imitation. In this sense, the salient function of the patent system may be closer to creating incentives to disclose innovations in the form of patents than to directing research by creating a reward. In fact, most patent systems have a dual function of providing a reward to elicit research and also providing an incentive to disclose innovations by creating property rights that protect innovations from imitation, although the latter function tends to be the less studied in the Economics literature.

Finally, we investigate the role of litigation in this industry, and in particular its substitutability with licensing. We find that this substitution does, in fact, appear to be occurring. We receive, however, mixed support for Lanjouw and Schankerman's (2001) hypothesis that smaller entities may face an entry barrier of higher litigation

costs than larger firms that have inventories of "spare" technologies that can be traded in order to stave off litigation. In our sample, smaller entities are small corporations – not individuals, as in their study – and do not seem to be suffering a lack of choice of using licensing arrangements to avoid litigation. In fact, they seem to be considering a wider range of strategies than this strict substitution. This may indicate that the Lanjouw -Schankerman entry concerns may apply more strictly to individuals than to smaller entities in general. We receive even more limited support for Lerner's (1995) contention that high litigation costs could cause research to be redirected away from litigious areas. Rather, we receive more support for the view that firms with high litigation costs may exploit their technologies by licensing them to firms with lower litigation costs, while leaving the area of research unchanged. In fact, if one re-casts the Lerner model with an option of licensing, this could easily be the result, as we will detail later. This would imply, in turn, that litigation costs are not a barrier to entry into research areas at the "design" level of this industry – even in highly competitive research areas -- even though they may be a barrier to enter the "hub" group.

We are not the first to use survey data to gather information on technology management. A recent series of papers[1] uses survey data to frame further empirical work on various technologies to address questions that are similar to ours. Our study differs in that it is focussed on GM food and its unique issues (such as the patentability of genes), as well as being quite recent. The latter allows us to check some of the hypotheses that have been put forward in the last few years regarding the role of litigation in intellectual property strategy. While supporting empirical work using a large data set would be desirable, there are several impediments to this in the area of our work. First, because GM animal and medical research involve very different competitor groups both at the product market and the research stages, our work is focussed solely on GM plants, limiting the amount of data potentially available for econometric analysis[2]. Second, genetically modified food is still, even at the time of writing, a new technology on which relatively little data is available even without the further area restrictions we have imposed. Finally, GM food research often represents only a portion of the overall research projects of the firms involved in

[1] See Hall and Ziedonis(2001), Ziedonis(2000), Sakakibara and Branstetter(2001) and Cohen, Nelson and Walsh(2000) for some examples.

the area. Using more general statistics on these research programmes could, then, be misleading to the extent that GM food represents a small percent of their overall research expenditure and so is not necessarily determinate in overall strategy. Our preference, then, is to present the survey on its own as suggestive of areas for future probing as the industry develops.

The paper will now proceed to describe our hypotheses. Next, we briefly discuss the survey. A copy of the survey questions is attached as an appendix at the end of this paper. We then present our findings in more detail. The last section of the paper presents some concluding remarks.

Our Hypotheses

As a first step towards discussing policy towards firms in the area of GM food, we need to define the scope of the industry. In particular, we need to know whether this industry should be considered, for the purposes of analysing behaviour, as separate from the traditional plant breeding industry, other areas of biotechnology, or any other group. In terms of our survey respondents, we need to know from them which entities they consider to be their competitors.

The definition of a market is a relatively explored concept in the area of competition policy and, in particular, merger policy. Mergers in concentrated industries are reviewed for their impact on welfare by competition authorities. Since concentration will tend to increase the more narrowly a market is defined, the definition of the market is crucial to determining whether this review will take place and on what terms. Clearly, too, the types of behaviour that could be expected of firms in a relatively concentrated industry would differ from those in a relatively fragmented industry.

At the heart of most concepts of market definition is the idea of substitutability. In merger policy, this is reflected in some measures of price elasticity of demand, or predicted price responses in the face of a hypothetical increase in industry

[2] Our scope includes genetic modifications to plants directly incorporated into food and genetic modification *techniques* applicable to plant-based food.

concentration. This type of exercise is particularly difficult to conduct for emerging industries: information on prices and products may not be readily available and substantial change in supply or demand conditions may occur in a short period, resulting in traditional analysis' giving only a fleeting glimpse of the industry. Simply waiting to see how the market will develop as it matures is not always an option, as merger activity in the early days of an industry can be quite frequent. GM food is a prime example of this, with extremely high merger activity in the late nineteen nineties[3] and moderate levels still continuing. As a result, the Competition Commission Guidelines allow the Commission to consider how rivalry may be expected to develop over time, relying on survey and other "soft" data in cases where hard information is limited[4].

The 1995 Antitrust Guidelines for Licensing Intellectual Property, used in the United States, extend the concept of market to "innovation markets", where such a market consists of "the research and development directed to particular new or improved goods and processes…and close substitutes."[5] Innovation markets give us an idea of the prospective universe of firms that will be product market competitors in the future, and hence are relevant to rapidly developing new fields, such as GM food. In this sense, we need information from our respondents not only on their product market competition, but on the competitors they face in research.

We used the survey as an instrument to elicit this information by asking our respondents which entities they viewed broadly as product market competitors, as well as how many products competed directly with their GM products[6]. Hence, we have questions set to investigate the following hypothesis:

Hypothesis 1: GM food constitutes a separate industry from non-GM food.

[3] Counting the activity of the top producers in this area only, over the last ten years there have been close to fifty mergers.
[4] See Competition Commission Guidelines (2003).
[5] 1995 Guidelines, Section 3.2.3, as quoted in Scotchmer (2004).
[6] A companion test would measure the substitutability of GM and non-GM crops more directly. This has been discussed, but no definitive measure of cross-elasticity has been developed to our knowledge. For more information on the usage and pricing of GM and non-GM crops, see Fernandez-Cornejo and McBride (2002).

Once the market has been defined, we need some measure of market power in order to discuss the structure of the industry as well as public policy towards it. Market shares in output markets are a standard measure, but current market shares in an emerging market may not be reflective of even near term structure. An alternative would be to build an intellectual-property based market structure measure as a means of implementing the innovation market concept. In theoretical models of patent design, patents often are taken as synonymous with monopoly power in output markets[7]. If we take this on face value, then it suggests that patent counts in subfields (such as corn or soy) could be used as a proxy for market power derived from the innovation market. There are several problems with using patent counts to reflect monopoly power, however. First, in many markets, survey evidence indicates that market power comes from factors other than patents, most notably learning by doing, secrecy, and sales efforts[8]. It should be noted, however, that the evidence varies considerably by industry, with drugs standing out as one where patents are viewed as highly effective. Before proceeding with a patent count, then, we must check with our participants that the standard conception from theoretical models that patents are important determinants of market power holds for this industry.

Hypothesis 2: Patents are an important "prospective" indicator of market power in this industry.

Second, pure patent counts do not correct for the difference in relative importance of patents in generating market power or for their cross effects in building patent portfolios that effectively create market power. Most patents, whatever the field, are relatively unimportant. This is true for GM food as well. For example, if one were to use forward citations by other patents as a measure of importance of patents, for all GM plant patents in the United States granted as of the end of 2000, 25% still had zero citations four years later and 53% had two or less. The equivalent percentages for our respondent sample are 37% with no forward citations at all four years on, and 80% with two or less. To address the patent count – market power link, Lanjouw and Schankerman (2004) develop an index of patent characteristics that can be correlated with economic value for firms and so can be taken as a measure of the relative

[7] For a summary of theoretical models of patent design, see Scotchmer(2004).
[8] See Levin et al. (1987) and Cohen et al. (2000) for relevant survey data.

commercial importance of patented technology, following on work by others[9] who have used forward citations as a measure of importance. For our work, forward citations will be retained as a primary measure of importance, as this is the part of the Lanjouw-Schankerman index that has the most salience in the related industry of biotechnology and as the other aspects of the index have less compelling justification in our sample[10]. For some examples where actual market shares are available several years later, weighted patent share measures are computed and compared with actual market shares as a means of discussing how accurate patent shares are in predicting market power for this industry. If they are accurate, then an implication is that the concentration of weighted patent portfolios can be an important candidate tool for evaluating future market power.

Finally, in the field of GM food where regulatory approval for commercialisation is required, patent counts – even weighted ones – do not account for the concentrating influence of the regulatory process. Where regulatory approval is very costly, this influence can be significant, so that patent counts should be taken – at best – as a probable lower bound on the true "prospective" level of concentration in GM food. We postulate two possible mechanisms by which regulation could concentrate this industry. First, firms with extensive experience with similar regulatory approval processes might have a higher level of expertise than those with little experience. This "learning" effect could give firms with more experience an edge early on in this industry, but might disappear over time as more firms gained similar portfolios of experience. A second mechanism is simpler: the cost of regulatory approval could serve as an entry cost to the industry, reducing the number of firms that this industry could support in the "downstream" stage after regulatory approval. This barrier could be expected to persist over time. Together, these two mechanisms could also lead to extensive licensing, as smaller patent holders attempt to avoid regulatory approval by selling their technology to their larger, and more experienced, rivals. Hence, we expect the industry to concentrate around firms with the "complementary skill" of

[9] For example, see Trajtenberg (1990). Also, see Hall et al. (2005) for discussion.
[10] The number of claims in the patent is the other part of the index that receives considerable weight for biotechnology in Lanjouw and Schankerman's work. In fact, the number of claims has increased considerably in the field of GM food over the last twenty years, but at the same time each individual claim has become far less cited. As a result, number of claims *alone* would appear to overstate the importance of patents with multiple claims. See Regibeau and Rockett (2004) for more discussion of number of claims as a measure of importance in the field of GM plants.

gaining regulatory approval, whereas a second tier of "design" firms produces patents as a final output for license to the firms with regulatory ability. Hall and Ziedonis (2001) note a similar "two tier" structure emerging in the semiconductor industry in the 1980s, with design firms not undertaking the (large and growing) cost of manufacturing facilities. Summarising, we have questions aimed at probing the following two hypotheses:

Hypothesis 3: Regulation has a concentrating influence on GM foods, due to the combined effects of expertise and (fixed) entry cost.

Hypothesis 4: Industry participants delegate regulatory approval by means of licensing agreements to a core of firms, resulting in increasing industry concentration at the approval stage and a "two-tiered" industry structure.

Within this two-tiered industry structure, we investigate the role of patents in generating research in the next few hypotheses. Above, we looked at whether patents were a good measure of market power. In the hypothesis below, we ask whether this is the *reason* why research in GM food occurs. This is certainly the presumption in many theoretical models of the effect of patents on R&D activity[11]. Sakakibara and Branstetter(2001), Hall and Ziedonis(2001) and Bessen and Maskin(2000) point out that one might expect that, to the extent that patents generate a reward to research, a stronger patent right would elicit more R&D. In fact, this connection is not supported empirically in any of these papers and is theoretically ambiguous even if patents are functioning effectively as "rewards"[12]. Delving deeper into the reward function of patents, survey results in Levin et al. (1987) and Cohen et al. (2000) suggest that managers do not find patents to be the most important generators of research "rewards". An exception to this is drugs, where patents are found to be viewed as important to generating innovative efforts. To the extent that GM food, as a subfield of biotechnology, may behave in a similar way to drugs it might be expected that patents would play a larger role here as well.

[11] See Scotchmer(2004) for a summary of this link in the literature.
[12] Some models of research indicate that stronger patents imply increased research expenditure, some do not. See Sakakibara and Branstetter (2001) and references therein. Intuitively, increasing patent strength may have more to do with the mixture of imitative and non-imitative research than the absolute level of total research expenditure, encouraging the latter and discouraging the former.

Hypothesis 5: Patents elicit GM food research through the "reward" that monopoly power creates.

On the other hand, if patents do not stimulate research by means of their reward function, it begs the question of the role of patents in generating scientific progress . Theoretical models of optimal patent design as well as legal work on the patent system[13] point to an alternative role for patents -- the "disclosure" function -- whereby the grant of exclusionary property rights on innovative results raises the incentive to disclose those results by reducing the ability of others to appropriate the gains of innovation. Such disclosure is crucial, the argument goes, for furthering scientific progress that builds on earlier results. If patents are, indeed, having such a function then they should be claimed to significantly raise the barriers to imitation. Hence, we can investigate this function within our survey population. In particular, if the response is positive, but the reward function response is negative, it indicates that an important avenue for future research on optimal patent policy would be to investigate more thoroughly the implications of the disclosure function of patents, as it may be the more salient aspect of the patent system for some populations.

Hypothesis 6: Patents function to increase incentives for disclosure of research results by raising the cost of imitation.

We are not just concerned with the amount of research conducted by firms, but also with the type of research. A particular concern that is unique to genetic engineering is the patentability of genes and its effect on research priorities. Harhoff et al. (2001) argue that patents on pure genetic material might not be as socially desirable as patents that require genetic material to be embedded in a particular application. The intuition for why pure gene patents might best be patentable is that, in a setting where innovation is sequential (so that later innovations build on the work of earlier innovations), the social value of the initial innovation should include the net social value of subsequent innovations. Second generation inventors should, then, be limited to recovering their costs, but all remaining surplus should be channelled to

[13] See Scotchmer and Green (1990) and Matutes, Regibeau and Rockett (1996) for a discussion of the legal and economic aspects of the disclosure function.

first inventors. As a practical matter, this would require broad patents on first innovations. In the case of GM, we could conceive of such broad patents as patents on genes regardless of their applications. Harhoff et al. (2001) argue that such a policy would be socially undesirable, however, because it directs research towards output that has relatively little social value: by raising the "prize" for the pure gene, it draws work away from applications of that gene, which is where more social value is generated. For example, herbicide resistant crops are an application of GM technology with a value to farmers that a specific gene by itself would not have.

With our survey, we can obtain views on whether pure gene patents would, indeed, have an effect on the direction of research. Hence, we have:

Hypothesis 7: Pure gene patents would cause research in this industry to be re-directed away from applications and towards pure genetic material.

The research area of genetic manipulation potentially has a very wide set of applications. Given this, we could ask whether firms tend to choose to "race" with each other on similar types of innovation or whether they choose very different trajectories to avoid each other. Clearly, the R&D race literature does not give firm predictions on this point: firms may rush to the same area despite competition because an application appears particularly profitable, or they may avoid each other in order to reduce the expense incurred by racing[14]. Lerner (1995), in a study of new biotechnology firms in the US, finds some evidence that firms avoid areas where other researchers have a "head start", but is able to go further to show that that firms with a high cost of litigation tend to avoid research areas populated by other firms – particularly ones with lower litigation costs. Hence, litigation costs appear to be "scaring" some firms off of certain research areas in biotechnology. This type of result might be expected to come through in our sample, as GM food is a highly litigious area. Although US patent litigation takes a long time to develop and work its way through the courts, one can observe from European data that patent oppositions in Europe are extremely high in GM food, at 25%. This is three times the opposition rate for biotechnology and pharmaceuticals, a seemingly similar field[15]. The level of

[14] See Scotchmer (2004) for a brief summary of some of the literature on patent races.
[15] See Harhoff et al. (2001)

experience with some form of patent litigation in our sample is similarly high, with 23% of our participants having experienced litigation involving the patents that form the basis of our survey.

While Lerner empirically verifies litigation's link to research trajectory for biotechnology as a whole, the theory rests on several assumptions that may not hold for our sample. In particular, it must be the case that litigation costs cannot be delegated by means of licensing agreements. Consider a simple conception of the Lerner model. Litigation cost is a characteristic of the firm, independent of the area of future research to the extent that it depends on size and past litigation experience, whatever the technology field. Hence, the population of firms has two types: low and high litigation cost firms. These firms may choose their area of research. Areas of research are of two types: areas where other firms hold patents ("populated") and areas where no other firms are working ("empty"). Assume that, if an area is populated, an existing patent holder will litigate any new firm patenting in the area. If the area is empty, no litigation will follow patenting. Suppose further that litigation is always successful. A prospective researcher chooses the area of research, then, by computing the profit of entering the populated area net of the litigation fee and comparing it to the profit of entering the empty area with no deductions. As long as the profit of the populated area is not high enough to overcome the cost of litigation, the empty area will always be chosen. For firms with higher litigation costs, the range of profits for which the empty area is chosen is larger. Hence, one can conclude that empirical work should indicate a stronger tendency for firms that are small or have no litigation experience to patent in "empty" fields.

Now, suppose that we consider delegating the litigation to a licensee with lower litigation costs. Suppose also that the licensor would change research area in the absence of a licensing agreement (so that the profits from changing field exceed those of staying in the populated area and shouldering the litigation cost). Hence, for licensing to occur, the licensor must earn more from the licensing agreement from the alternative of changing field. Suppose further that, at the lower litigation cost, research in the populated area is more profitable, taking into account litigation, than research in the empty field. This means that litigation expense is the determining element of the decision, our case of interest. In this case, there will be surplus left

over after the minimum license fee to induce participation is paid to the licensor. Still, the licensee will only accept this delegation if the revenues from the patent net of the (low) litigation fees exceed the profits it would make by refusing the license. As long as this alternative profit is small, then the licensee will always accept and research should be conducted in the populated area. Therefore, no change in research area occurs due to the litigation expense. Rather, firms organise litigation "efficiently" by delegating to the low cost firm whilst remaining in the populated area of research[16].

Other considerations could be added as well, but the main point is that if licensing can be used as a tool to delegate the litigation process it separates the research from the litigation decision so that, while litigation and licensing strategy would be expected to be heavily related, litigation and research strategy might not. At the very least, it could weaken the effects pointed out by Lerner. We investigate, then, the research decision and the role that licensing and litigation play in that decision with the following hypothesis:

Hypothesis 8: Licensing is used to delegate litigation costs in this industry.

Related to this, we consider other effects that the threat of litigation has on the marketing strategy of our respondents. In particular, Hall and Ziedonis (2001) as well as Lanjouw and Schankerman (2001) have suggested that litigation should rise as the cost of alternative strategies to resolve patent infringements (specifically licensing and out of court settlement) rise. These alternative strategies should be more available to firms that have technologies available "off the shelf" to use as bargaining chips in cross licensing agreements, and so creates entry barriers for smaller entities. This leads us to our last hypothesis:

Hypothesis 9: Litigation is a higher entry barrier for smaller entities in this industry than for larger entities.

[16] If patents tend to be complementary, being used within areas of research to build patent portfolios or being used together to generate the technology underlying a particular product, then the argument can be made stronger that the licensor would wish to remain in the populated field. This is because a blocking patent that is key to the strength of a patent portfolio owned by the licensee could result in a better bargaining position for the licensor in the negotiations.

The Survey

We used patents from the USPTO and the EPO websites to construct a universe of granted patents up to the end of year 2000 in the area of GM food based on plants. We screened each patent by carefully reading the claims in order to classify the patent as applying or not applying to GM food. This method was much more accurate than the standard method of using patent class as a criterion for selection, as there is no single patent class for that adequately captures GM food, and GM food alone[17]. Our procedure resulted in a universe of 141 entities that were listed as assignees for patents on GM food. This was our list of possible survey recipients worldwide. We attempted to contact each of these entities in order to obtain agreement to respond to the survey. This was not always possible. For example, we were able to obtain no contact information for individuals holding patents in this area. In all, 96 of the entities we were able to contact agreed to participate and received a survey. Of these, we have collected 26 completed surveys. Clearly, we could not compel entities to respond, so our sample does not necessarily represent a random selection. Our sample does, however, represent a diverse cross-section, having the following characteristics:

	US	Canada	Europe	Other
University	9	-	1	-
Small Firms	4	1	-	
Large Firms	-	-	5	1
Gov. Agencies	-	2	1	2

[17] For example, the 800 class groups all plant patents, whatever the technology that generates them. Class 435 relates closer to genetic manipulation but includes plants, animals, and some medical applications.

While we divided our responses from firms into those under 1000 employees ("small") and those over 1000 ("large") employees, the actual responses fell into a "small entity" group composed of fewer than 200 employees and a "large entity" group composed of over 2500 employees. As a result, small firms refer to *very* small firms in our sample, while large firms are very large.

In each case we asked to speak with a person who was knowledgeable about the questions we asked. As our questions touched upon a number of different policies (research strategy, patenting, litigation, product market competition and so on), there were times when we had to contact a number of different people within the same enterprise to obtain informed responses. Further, we attempted to have questions that could be "matched" to detect inconsistencies in the answers, possibly related to misrepresentations reflecting particular agendas supported by survey participants, as well as to balance responses from respondents with different characteristics (and so, perhaps, opposing agendas). Hence, our discussion of the hypotheses often relies on taking several responses together to form an overall narrative rather than on single responses. We also supplemented the paper version of the survey with telephone contact, which was aimed both at making sure that the survey represented the true rather than the biased views of the respondents, as well as at clarifying any confusions. Overall, we detected relatively few contradictions that would lead one to be suspicious of the veracity of the answers; however, the responses represent at best the *perceptions* of *some* industry participants, which are undoubtedly coloured by the type of organisation that the respondent represented and the experience that each organisation had had in this field. Finally, we collected the data under a confidentiality agreement that only allows us to release aggregated responses in the discussion that follows.

Findings

Discussion of Hypotheses 1 and 2: Industry Definition and Patents as a Measure of Market Power

Our first hypothesis was that GM food represented a different industry from others, specifically from traditional breeding and other biotechnology. We asked respondents

how many firms were viewed as important product market competitors and, in a separate question, research competitors. Respondents were also invited, but not obliged, to name competitors in each market. Overall, just under half (46%) cited at least one competitor in the relevant product market. The named competitors were drawn overwhelmingly from the same set of large research and manufacturing firms[18]. This set provided little support for a hypothesis that competitors were drawn from traditional breeders or biotechnology firms outside of agricultural applications. Furthermore, those naming competitors listed the same research competitors as product market competitors, suggesting that the "invention" market is comprised of, for all intents and purposes, the same group as the final product market[19]. In fact, the attention seemed to be focussed on a core group of large firms ("hub"), with a fringe of entities ("spokes"), largely in separate applications, working on development only and not viewing each other as competitors[20].

Those not listing competitors fell into two groups: those that said definitively that they had no important competitors and those that did not know to what use their technology was being put[21]. Interestingly, half the universities named firms as important research competitors, and those naming firms listed the same group of large firms as the others[22]. This could suggest two things. First, it could suggest that universities could be considered as part of the "spokes" of this industry, contributing technology by license to the core group. Second, it could suggest that this is an area where there is considerable similarity between the research agendas of firms and universities (or government bodies). In fact, while Henderson, Trajtenberg and Jaffe (1998) find that university research is more "general" and more "important"[23] than

[18]Of the competitors that were named, two out of seventeen could be considered small. One of these small firms has significant investment by very large partner firms that were members of the group consistently named by others as the competitor set.
[19] In fact, even those that *did not* name competitors indicated that the research competitors were generally the same as the product market competitors.
[20] Only one firm listed another set of small firms as working in a similar area.
[21] Note that these were all universities or governmental bodies with process technologies on license to other entities. Those not knowing to what use the patent had been put were not necessarily those charging a zero license fee. One could perhaps infer that these were cases where a standard licensing contract was negotiated, based on a royalty plus a fee that was designed to cover the cost of the research so that the actual use to which the technology was put would not be vital to knowing how to set up the license.
[22] Universities also listed the same firms in the product and research markets when they were named and, even when they were not named, generally noted that the two groups were the same.
[23] For a discussion of these measures and of university patenting, see Henderson, Jaffe and Trajtenberg (1998) and Trajtenberg, Henderson and Jaffe (1997).

corporate research across a wide variety of fields, Conti, Regibeau and Rockett (2003) find empirically that there is much less difference in the field of genetically modified plants. This survey, then, does not provide evidence to contradict the relative similarity of university and corporate work in the area of GM food[24].

Our respondents appear to view themselves as truly having some monopoly position. When asked whether the product in which their GM technology was embedded (either produced by themselves or by another firm under license) had a direct product market competitor produced by another entity, the *unanimous* response was in the negative[25]. Clearly, then, each of these respondents derives at least some degree of market power either directly or indirectly from the technology. The research competitors cited on the surveys should, then, be viewed as working in the same *general* research area, but perhaps not developing precisely the same applications as the respondents. It also is likely that, taking these results together, while the precise research results may be unique at least some members of the hub group have enough know-how to pursue competing research if they so desire. This suggests that, without patent protection, an exclusive hold on the technology would not be secured.

We pursued this issue by attempting to determine more directly whether *patents* were the source of this market power. When asked by how much a lack of patentability would affect profits, those companies with products currently on the market responded, on average, that profits would drop less than 10%. A problem with interpreting this response, however, is that it does not correct for the importance of the patents: if most patents are, indeed, "unimportant" then the bulk of them would tend to have very little effect on profits of firms. In fact, the survey response distribution of patent importance -- as measured by forward citations by other patents -- has a median number of net citations received in the first four years of the patent's life of 1 (compared to 0 for all GM plant patents in the US through the end of 2000) but none over 3, missing the (slightly less than) 10% of the (US) GM plant patents that have

[24] As an aside, there was no systematic difference between the views of private and public universities in any of our survey responses.
[25] We verified this by requesting an estimate of the price elasticity of demand, obtaining estimates that were consistent with a considerable degree of monopoly power in the output market overall.

more than 3 net citations in the first four years[26]. Hence, while our survey does not reflect a less important set of patents than the broader population, (as reflected in the medians) our do responses tend to reflect patents that are "run of the mill" rather than those that are very important since we do not have any observations from the "right hand tail" of citations distribution. Still, it is significant that even these "run of the mill" patents can account for a 10% effect on profits for this group. We follow up, then, with a question more directed at the role of patents in creating market power by asking by how much cost and time of imitation increased due to the patent. Here, firms generally responded positively, with an average rise in the cost of imitation of approximately 42% and an average increase in the time of imitation of 28%[27]. There was wide variance in these numbers, ranging from zero to "prohibitively expensive" in terms of time or money. Still, in light of this, perhaps the way to interpret the responses is that the patent is "doing its job" in creating a relatively effective barrier to imitation, but the distribution of patents in our survey reflects the general distribution of patents is that most are at best modest sources of revenue. This suggests patent counts may be used to measure market power, but they should certainly be weighted by importance if they are to reflect actual or potential commercial strength in the market.

Suppose that we were to implement weighted patent shares, then, as a measure of prospective market power for this industry to evaluate a merger. For example, we could take all patents granted in the industry (or for the crop in question) up to four years before the proposed merger date and then track the citations measured during the first four years of the life of each of those patents (relative to the total population of patents that might have cited it) as a measure of its importance. Each merging entity's market share would, then, be reflected in its share of the total patents with each patent weighted by its importance relative to the average importance for the

[26] As our survey tends to reflect more recently-granted patents than the overall population of GM plant patents, we choose to measure importance as the citations during the first four years of life rather than the entire lifetime citation pattern, as this latter measure would systematically favour earlier patents. Net citations refers to citations net of self citations. If the citations were to include self-citations, the point would remain the same, however, as the percentages differ only slightly.

[27] As a comparison, Mansfield(1986) finds that most imitation costs (69% of his sample) rise less than 20% due to patenting in a study of 33 products across a variety of industries. 18% of his sample have a percentage increase of 100% or more. For our sample, and focussing on for-profit firms, we have 35% listing no increase in imitation cost, ¼ listing a 25% increase, ¼ listing a 50% increase, and 15% listing a prohibitive increase. This is a somewhat more favourable distribution than Mansfield's but holds for an industry where we might expect patents to be more powerful.

entire population. As an example, if we were to do this as of the year 2000 we would obtain a prospective estimate of US market shares – based on US patents -- for corn of only 23% for Monsanto when we do not apply the weighting but 43% when the weighting is applied. For soy, we obtain figures of 17% when for Monsanto when we do not apply the weighting and 28% when we do[28]. Clearly, correcting for importance makes a huge difference to these figures[29].

Does this represent an accurate prospective measure of actual market shares? In order to do this, we need to let some time pass. While it is a little difficult to get agreement as to Monsanto's US market share and how to measure it[30], a rough estimate is that Monsanto's current actual market shares in the United States for corn and soy are 49% (up very slightly from 43% each year since 2000) and 90% (down very slightly from virtually the entire market each year from 2000). These are both higher than our "prospective" measures, above. While the corn figure is not very different from the weighted patent estimate, the soy figure is quite far off. The explanation for this large difference may be the strength of certain soy patents that are underestimated by the citations count: some patents now owned by Monsanto underlie almost any GM soy currently grown. In other words, to produce in this field, a license of some basic technology is very important, leading to the high share of Monsanto technology in this crop. Subsequent research (which would be reflected in the citations count) has not yet done justice to the importance of the Monsanto patent portfolio in the current soy market. This would generally be true of citations based measures: extremes of market importance would be relatively poorly measured by even weighted citations[31].

[28]This calculation is based only on patents that specifically make claims applying to the crop in question.

[29] Normally, one would want to take into account, in a weighting measure, the expiration date of patents. In the case at hand, however, the patents are recent enough that their expiration dates are not a major factor entering into the weighting.

[30] Market shares can be calculated by trait or by seed. The corn figure is the percentage of the genetically modified crop planted accounted for by Monsanto's brand of GM seed, including licensing. The second is the percentage of US planted acreage with Monsanto traits, even though the seed may not be sold by Monsanto. Clearly, this is heavily influenced by licensing activity as well. Even these estimates vary substantially depending on the source, however, leading to their designation as "rough". Estimates of market shares can be found in Casale(2004) and McMahon(2004).

[31] Figures for other firms in corn are 13%, weighted and unweighted, for Du Pont, 15%, weighted and unweighted, for AgrEvo and 4% weighted but 17% unweighted for Syngenta. Dow's market share, weighted and unweighted, is negligible based on intellectual property measures. This can be compared to reported market shares in corn of 40% for Du Pont (through Pioneer) and 15% for Syngenta. (Others were unavailable.) The Du Pont figure, unfortunately, includes a non-GM component and so is

Hence, the corn and soy figures illustrate an advantage and a disadvantage of taking the innovation market information into account as a prospective market share measure: when technologies are quite powerful, their influence may be underestimated in weighted patent counts. On the other hand, in the moderate ranges, the measure can perform relatively well. Still, if we take the patent count calculation seriously, it would suggest several things. First, in terms of soy, one would be concerned about increased power by a company like Monsanto in the seed industry, as a powerful patent position in the seed-making technology as well as seed production facilities would raise the possibility of foreclosure[32]. This supports some recent decisions to enforce licensing of technology as part of acquisitions in this field[33]. Second, in terms of corn, our "prospective" measure is quite close to the actual market share measure, suggesting that no near term changes would normally be expected based on the measured technology position. Still, the absolute measure is quite high, suggesting that further consolidation might be a subject of concern. For soy, the intellectual property is not nearly as concentrated as the market, suggesting that concentration figures should drop from their current extremes.

Hence, we have found support for relatively high concentration of this industry and for the use of weighted patent counts as a prospective measure of market power. We have also found support for a "hub and spoke" pattern, with a relatively small number of large firms being the product and research market focus and many smaller design firms providing technology to the large firms, but not competing head to head with each other. We now turn, in the discussion of the subsequent hypotheses, to the role of regulatory approval, patents, and litigation in generating this structure.

Discussion of Hypotheses 3 and 4: The Role of Regulation

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not directly comparable to the intellectual property shares. For soy, the only other company to hold a significant patent portfolio is Du Pont, with an unweighted and weighted share of 33%. All figures are computed using the most recent acquisitions to attribute patents to firms, but not any other marketing arrangements between firms.

[32] Monsanto has acquired a number of seed producers in recent years. Most recently, it has acquired Seminis (February, 2005). Seminis does not currently have a strong position in soy, however.

[33] See Hayenga(2003) for a summary of some recent decisions.

We asked several questions to investigate the role of regulation in this industry, and its effect on competition (specifically on industry concentration). First, we asked entities to map out the regulatory process to which they had had to submit their GM technologies. Next, we asked about the level of costs (relative to profits) of this procedure, the relative burden that regulation imposed in terms of increasing the time to market of the technology, the change in cost of obtaining regulatory approval as the number of submissions increased, and the effect of a change in regulatory approval cost on licensing strategy.

Most entities in our sample were not directly involved in regulatory approval: only 15% of our respondents had, themselves, submitted output to a regulatory process beyond patenting. While this might appear surprising in such a highly regulated area, it has ready explanations. First, some entities stated that they were participating in process technologies (such as technologies to induce a certain trait in any plant), so that regulation applied to the plant that was modified rather than to the process itself. For others (a further 15% of the sample) were using the patents in question merely to strengthen existing patent portfolios, rather than to contribute directly to the creation of a product, so that regulatory approval for output based on the patent was not being contemplated.

More importantly, three quarters (77%) of the sample were obtaining revenues from the patents by means of licensing agreements. Many licensors commented that all regulatory costs were handled by the licensee and, as such, regulatory costs were not of direct concern to them. Hence, delegating regulatory approval by means of the license was a regular practice in our sample. We pursued this by asking about the effects that a change in regulatory cost would have on licensing strategy. Some, including both firms and other entities, indicated that they had no realistic alternative to licensing: manufacturing was not an option for them. Hence, they claimed, whatever the cost of regulatory approval, they would continue to license equally intensively as long as their research costs were covered. This says two things. First, the design firms were delegating both regulatory and manufacturing costs through the license, seemingly considering both a barrier to entry. More interestingly, it appears that the main point of the license was to recoup the cost of research, leaving a large enough surplus to the licensee that even further increases in regulatory burden would

not be likely to affect the propensity to license, even though it might affect licensee margins.

The regulation that applied to the firms that actually had participated directly in regulatory approval varied substantially, with some reporting a very light and short burden, and others reporting a complex process taking up to ten years. Similarly, the percent reduction in profits due to the regulatory process varied from (virtually) 0 to 75%, with the higher figure associated with a complex and lengthy procedure involving approval by a variety of agencies. Hence, the degree of potential entry deterrence that regulation creates was very uneven across our sample, when one considers those firms that actually submitted products to regulators. Not surprisingly, the degree of reported regulatory burden was correlated with the response to the question of how much a 10% increase in regulatory cost would affect licensing activity: the higher the entity's reported regulatory burden, the larger the increase in licensing out that the entity said that it would conduct in response to a further increase in regulatory cost. Similarly, a larger propensity to license in was reported by the larger firms in the sample as a response to larger regulatory cost. This lends support to the comments made by current licensors that licensing is a standard tool to delegate regulatory approval in this industry, resulting in increasing concentration at the approval stage as regulatory burden increases.

In terms of learning effects, the responses that cited multiple use of the regulatory system reported relatively fast learning, with all learning reported as having occurred after a single regulatory experience, and a percent reduction in cost of regulatory approval upon increased submissions that was relatively modest (on the order of 10%). While this would reflect a relatively modest learning curve, it is the response of entities that actually chose to submit products themselves: the firms that perceived the process as too onerous – and as a result licensed out -- would not have reported a response to this or other regulatory questions. Still, this response does not lend strong support to the need to help firms *learn* about the regulatory process in order to promote entry.

In sum, there was some support for the hypothesis that regulation is a concentrating influence in this industry, and that it may discourage entry into the

approval stage even if it does not hamper entry into generating new technologies at the research stage. Learning effects, while they are present, appear to be relatively mild and to occur with relatively few submissions. Hence, we appear to have some support for regulation's playing a role in generating a two-tier structure in this industry for those technologies subject to a large regulatory hurdle, but also a suggestion that this is *not* a short term phenomenon that could be overcome by sponsored learning.

Discussion of Hypotheses 5, 6 and 7: Patent Policy in GM

We asked several questions to elicit the role that patents were playing in this industry. These included questions about whether patents were a way of stimulating research in this field, the precise nature of the protection that patents afforded the researchers, the opinion of the respondents on whether genes alone should be protected and, more concretely, whether the respondents would change their research plans if patents on genes alone were made available. Conversely, we also asked whether the lack of patents on GM technology would decrease research in this area.

The overwhelming majority of respondents, firms and universities included, thought that their research spending in this area would not have decreased if patents had been *un*available on GM innovations. Unsurprisingly, no universities found patenting to be relevant to their research decision. More surprisingly, few more of the companies did. Even when we looked only at the firms that were continuing to receive patents regularly in this area (in other words, those that listed further patents in the area of GM food that they had received since the end of 2000), the responses did not give a greater weight to patents in terms of stimulating research. One reason for this is that some patent holders – including firms -- reported receiving compensation in ways other than direct patent "rewards". Specifically, research funds from an external source before undertaking research were cited in several instances[34]. As long as research costs were covered, these entities noted that this funding determined whether the research occurred and what the subject of the research was: the patent position did not have a *direct* effect. For these firms, any income from

[34] These included direct grants and general corporate funding (such as venture capital).

licensing the patent was viewed as “icing on the cake”, but was not determinate. In this sense, the design firms seemed “one step removed” from any incentives that patents might create. A second reason was that just over half of the companies commented in the margin that GM was not the main line of research of the company. Instead, one can infer from the comments that the GM patents were either offshoots of other research programmes or a way of keeping abreast of a new developing field, but not a main strategic area of development. In this sense, patentable innovations in this area were "fortuitous" for these firms, rather than planned revenue-generators: they contributed to the existence of the firm, but their revenues were not determinate to its research focus.

In order to verify the role of patents, we asked several more questions regarding the reasons for patents to have value in this area. While universities continued to view patents as unimportant to their research agendas, almost half the relevant firms reported that profits would fall if GM innovations were *not* patentable. In other words, while the research would have occurred in the absence of patents, the patents were still, in fact, contributing currently to profits. This implies that patents must be raising the overall returns to the entity and so increase the returns to research as an activity even if they are not the reason that particular research trajectories are chosen. Hence, we receive some support that patents do create a “reward”, but this reward is not what determined whether the research supporting these patents had been chosen.

As was mentioned earlier, patents were viewed as contributing significantly to increased imitation cost or time by our respondents. One interpretation of this apparent imitation barrier is that patents are functioning as relatively effective property rights, mapping out areas of exclusivity for their owners. In turn, this implies that the role of the patent in increasing the incentives to disclose research progress may be important. For some of our sample the disclosure function was noted explicitly as the reason to patent: universities and non-profits stated that the patent was being used as a way of “getting information out”. Further, these entities indicated that their answers to the effect on imitation cost and time were affected by their eagerness to disclose: they felt that the patent would not increase imitation cost partly because they intended to *facilitate* future research in the area. For firms, the imitation cost and time effect was much higher, suggesting that the patents’ exclusionary rights

potentially had "bite" in terms of increasing appropriability even if universities and non-profits did not choose to take advantage of this[35]. Interestingly, this disclosure function of intellectual property protection has received little attention in the Economics literature, despite the weight given to it by this population.

Finally, we asked all respondents to give an opinion on whether patents in this area should be available on genes alone and, if they were, what difference this would make to their research. Consistent with our other responses on the effect of patents on research trajectory, we obtained only negative responses to the first question and only a single positive answer to the second. As there are ethical and legal ramifications of granting patents on genes alone, these responses may have been motivated by purely non-economic considerations. Unfortunately, no respondent chose to elaborate on their reasons. Still, we are left to conclude that our survey indicates no support that change in patent "breadth" would have an effect on the direction of research, as reported by those currently in the field[36].

Our conclusions regarding patent policy from this section are, then, mixed. While patents clearly play a role in generating revenues for the entities involved, it is not clear that these revenues are the reason that the specific research occurred in the first place, even for private firms and those continuing to work in the field. Hence, while a role for the "reward" function of patents exists for the sample in that profits would generally fall in the absence of patents, the more salient function of patents that came through in the survey was to create property rights that effectively raised the barrier to imitation. In this sense, the relatively under-studied role of patents in encouraging disclosure of results came through strongly in the sample. Perhaps the responses reflected the view of many of our respondents that they were "one step removed" from the patent system as a means of generating research. Consistent with other responses on the lack of patentability's effect on research priorities, all but one of our respondents felt that pure gene patents would make little difference to the type of research they are doing.

[35] Perhaps surprisingly, the one group that appeared to regard patents as an important means of eliciting research in this area was the governmental category. On the other hand, other responses indicate that the income from the patents was not a primary concern to this group. Perhaps this has something to do with the compensation systems in these agencies.

Discussion of Hypotheses 8 and 9: The roles of litigation and licensing

A final area of concern was the enforcement of patent rights, and the role of litigation in intellectual property management. First, we investigated the views of participants on the cost burden of litigation. Second, we explored strategies of reducing or avoiding this cost. While we asked directly about licensing as a strategy for avoiding litigation, we also obtained confirming evidence (to be discussed below) that licensing was a rather standard response to potential or actual litigation. In order to obtain information about the relative bargaining positions of the firms performing the licensing, we asked about the percentage of profits that the licensor attempted to recover from any licensing out and the structure of the licensing contracts.

We had understood before starting our work that licensing activity was extremely high in GM food. As we mentioned earlier, this was confirmed in our sample. For our participants, licensing contracts have primarily an up-front fixed fee plus royalty structure, although a minority of our respondents (27%) had a percentage of their earnings coming from either pure royalty or pure fixed fee contracts. On average, just over half (51%) of the contracts issued by these firms were exclusive. Covering the cost of patenting was noted by several respondents as the reason for the fixed fee. Finally, the percentage of profits that entities attempted to recover was either quite high for the for-profit firms (averaging 62%) or zero for the non-profits, universities and other entities. In the latter case, presumably licensing attempted to cover the costs of the patent only, even when a royalty was used as part of the contract.

Based on our survey, it appears that licensing plays a series of roles in this industry. As was mentioned earlier, it clearly is a major source of revenue for a number of our respondents, constituting 100% of revenues in a number of cases. Further, these respondents anticipated a significant share (more than 80%) of the profits generated by the technology, indicating a relatively strong bargaining position in this industry for licensors. Licensing also plays a role in avoiding litigation, however, ranking as the strategy of choice to respond to litigation for 42% of our

[36] A single firm did stand out by responding positively to this question. This firm also viewed patents as more important in directing research in general than other respondents.

respondents. Cross licensing came in as the strategy of choice to avoid litigation for 30% of our respondents. Six respondents cited various other strategies, including conducting new R&D and threatening litigation to avoid litigation. When asked directly whether a rise in the cost of enforcing the patent would result in an increase in licensing activity, 42% responded positively. This appears to reflect a strong view that licensing is a standard response to litigation and further that the higher the litigation costs, the more licensing (out and in) one might expect.

The ranking of cross licensing and licensing to avoid litigation did not appear to depend on the size of the entity, with small entities actually listing cross licensing as the preferred response more frequently than large entities. The larger firms had far more litigation experience surrounding the patents in question in our survey, although they also tended to have older patents so that their exposure per patent was longer. Further, it is not the more important patents in the sample that are the more litigated patents. In fact, the more litigated ones tend to be somewhat less important than the average[37] and have almost exactly the mean number of backwards citations. Hence, one cannot conclude that our sample represents a case where more important patents, patents with a longer genealogy or patents belonging to smaller entities tend to attract more litigation. In this sense, our sample does not reflect the concerns of Lanjouw and Schankerman that certain types of patents or patent holders tend to attract litigation.

Several comments are in order here, however. First, our sample does not include individuals. These are contrasted with corporations in the Lanjouw and Schankerman paper to make the points that smaller entities might be involved more frequently in litigation as opposed to licensing arrangements. Our responses would suggest that perhaps this sort of bias may apply more to individuals than to even quite small corporations, as even the small firms in our sample appeared to be "playing the licensing game" as much as the big players. On the other hand, and more in line with Lanjouw and Schankerman's work, it was exclusively small entities in our sample that listed litigation as a response to the threat of litigation, albeit sometimes qualified by specifying that a partner would have to be found in order to bring litigation.

[37] Again, importance is measured by net forward citations in the first four years of the patent's life corrected for the size of the potential citing population at the time of grant.

The fact that litigation and cross-licensing both are listed relatively frequently as preferred strategies for smaller firms leaves us with a bit of a puzzle. The explanation for this may be that size in terms of employees does not necessarily correspond with size in terms of stock of technology. Those that have little to trade could be those volunteering litigation while those that have much to trade would not. It could also suggest that litigation and cross licensing are viewed as complements, by some of these respondents rather than as substitutes. Clearly, this is a very different conception of the relation between these two instruments. It may also be that cross-licensing has a cost that is not much lower than that of litigation when one takes into account the implicit cost of licensing when it was *not* optimal to do so in the absence of the possibility of litigation. In this sense, cross licensing and litigation could be alternatives between which some respondents were indifferent. The indifference could lead to the ambiguous ranking of these alternatives. Third, our smaller entities appeared to be considering a larger list of alternatives than just litigation and cross licensing alone: partnering along with litigation may be one way of addressing the Lanjouw-Schankerman concerns in a highly litigious industry. In fact, Harhoff et al (2001) find that some litigation is more broadly based in GM food than in other parts of biotechnology. Finally, to the extent that higher litigation rates in this industry reflect less selection about who gets litigated, it may simply be that there is less selection of the type that Lanjouw and Schankerman observe occurring for this group. In short, our responses indicated that further study of this issue would be important, as the interaction between licensing and litigation could be fairly complex.

Our respondents stated *unanimously* that a change in litigation cost would not affect research focus. The one that indicated that a rise in litigation cost would affect research indicated that it would need to work harder to create a stronger patent thicket, not that it would change research focus. In this sense, we received no confirmation in our sample for Lerner's theory of a link between litigation cost and research trajectory. This is somewhat surprising given the litigiousness of the area. Further, for those respondents listing infringement or invalidity suits as part of the total cost of maintaining their patents in this area, these costs averaged a significant 20% of the total costs of patenting (including research costs). In addition, those firms that noted that they no longer worked in the GM food area were exclusively large

whereas those that noted that they were continuing to work in the area were exclusively small, with a mix of litigation experience in both groups. This is not consistent with high litigation cost driving firms into other areas of research: it should be the small firms (those with a high cost of litigation) that are leaving. There may be an explanation for this that is consistent with Lerner's results, however. As was mentioned above, our respondents reported a strong linkage between litigation cost and licensing activity. In fact, a number of respondents specifically noted that licensees were handling all litigation costs. As our section on hypotheses stated, once licensing is introduced, the research-litigation link can be broken. In fact, this may be precisely what is occurring for this sample.

Hence, it appears that licensing is used to delegate many costs in this industry: litigation costs, regulatory costs and manufacturing costs. While this has implications for a relatively concentrated "hub" at the centre of the industry, it also implies that firms that view themselves as "inefficient" at litigation or regulatory approval can participate at the research stage and license the technology rather than avoid the research area altogether.

Conclusions

Our survey responses have suggested several conclusions about the GM food industry. First, the industry appears to be separate and highly concentrated, comprising a small hub that conducts research, regulatory approval and manufacturing and a large number of spokes focussing on technology provision to the hub. The concentration levels for both innovation and current market provision of approved GM food crops appears high compared to normal triggers for scrutiny of further merger activity. Licensing is undertaken to delegate regulatory and litigation costs to the hub, resulting in the "two tier" structure of the industry. Regulatory costs appear to be barriers to entry to the hub, but not to be primarily due to learning economies. In this sense, they are persistent concentrating influences, not likely to be largely affected by sponsored learning for industry participants. Patents, while clearly generating income for industry participants, do not appear to be directing research through their reward function. In particular, we did not receive much support for the idea that targeted changes in patent scope – and in particular, patents on pure genes --

would affect research trajectories in this field. Finally, litigation appears not to affect research trajectory heavily in our sample, perhaps due to the interaction between litigation, research and licensing strategies. Clearly, as our sample is small and not necessarily random, all these conclusions must be qualified as suggestive rather than definitive.

Our responses also suggested several areas for future work. First, weighted patent counts fared relatively well to predict moderate concentration levels, but fared less well in predicting extremes of concentration for this industry. The contribution of weighted patent counts to the implementation of the innovation market concept to measure prospective concentration in an industry could well be evaluated across a wider set of industries and a wider time period. Second, our responses point clearly to an important interaction between licensing and litigation. The nature of this interaction is not, however, completely clear. These alternatives are not necessarily substitutes in all cases, licensing is not necessarily the only alternative considered to litigation, and the implicit cost of licensing compared to that of litigation is also difficult to judge. Third, our responses pointed to a relatively important role in intellectual property strategy for disclosure and perhaps less emphasis on reward. This bears more investigation, as the disclosure function is the less studied of these two functions of patents.

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Appendix A: Survey

A copy of our survey follows. A separate page was sent to collect basic company information (such as number of employees, country of incorporation and so on).

Survey Number

Survey on Patents, Regulation and Genetic Modification

Thank you for participating in the survey. The questions in the survey refer to the following patents, which the USPTO (U.S. Patent and Trademark Office) or the EPO (European Patent Office) indicate have been assigned to you and which have application to the area of genetically modified food:

If you are aware of other patents that you hold and are applicable to GM food, please indicate their numbers here:

This survey asks you questions regarding the research leading up to the patents listed above, and the impact of patent policy and regulatory policy on your decisions to participate in this area. Many of the following questions ask for percentages. These refer to *approximations* by you of the actual percentages in each case. Further, we have asked some hypothetical questions. We are interested here in your *opinion*. In all cases, we are interested in *your* experience and *your* opinions, not those of other companies or individuals who have participated in this field.

Thank you for your participation.

Dr. Pierre Regibeau Dr. Katharine Rockett

1. Have any of these patents reached the commercialisation stage, or are they still under development?

   Some commercialised Development only *(circle as appropriate)*

2. Which of the following is the *primary* source of revenues from each of these patents? *(please write a letter next to each patent number on the front page of this survey)*

   a. Embodiment in a process that *your* company uses?
   b. Embodiment in a product that *your* company sells?
   c. Through licensing contracts to other firms?
   d. Through cross-licensing agreements with other firms?
   e. Indirectly, through increased sales of other products your firm produces (for example, increased sales of herbicide as a result of GM seed sales)?
   f. Through strengthening your intellectual property protection of other innovations (for example, by creating a defensible patent position by protecting the process from which a product is created as well as the product itself)?

3. For the patents that are embodied in products, which of these products has a close substitute that is produced by a *competitor*? (Write the patent numbers below)

4. For the patents that are embodied in products, which of these products has a close substitute that is produced either by *your firm* or with patents that you have on license to another firm? (Write the patent numbers below)

5. *On average*, what *percent* of your actual R&D spending on GM would you have made if this type of innovation had not been patentable?

   _____ 0% (patents are irrelevant to your R&D spending)
   _____ 25%
   _____ 50%
   _____ 75%
   _____ 100%

6. There is still some uncertainty on whether claims covering genes *alone*, that is, without any corresponding function or application, will be granted and upheld in court. In your opinion, would granting and upholding patents on genes *alone* be a good idea?

Yes No (circle as appropriate)

7. If claims covering genes *alone* were granted and upheld, would your company *increase* or *decrease* its spending on research and development in the area of genetic modification?

_____ the change would not affect our research and development spending

_____ 25% decrease	_____ 25% increase
_____ 50% decrease	_____ 50% increase
_____ 75% decrease	_____ 75% increase
_____ 100% decrease	_____ 100% increase
	_____>100% increase

8. Suppose that patent protection were not available on GM. Give the *percentage* by which your company's profits from the products currently protected by your GM patents would change.

_____ 0%

_____ 25% reduction	_____ 25% increase
_____ 50% reduction	_____ 50% increase
_____ 75% reduction	_____ 75% increase
_____ 100% reduction	_____ 100% increase
	_____>100% increase

9. By what *percentage* do these patents increase the imitation <u>cost</u> of other companies?

_____ 0% (patents are irrelevant to imitation cost)
_____ 25%
_____ 50%
_____ 75%
_____ 100%
_____ >100% (but not prohibitively expensive)
_____ imitation prohibitively expensive

10. By what *percentage* do these patents increase the imitation <u>time</u> of other companies?

_____ 0% (patents are irrelevant to imitation cost)
_____ 25%
_____ 50%
_____ 75%
_____ 100%
_____ >100% (but not prohibitively expensive)
_____ imitation prohibitively expensive

11. *On average*, how many years do you anticipate it will take for your firm to recoup its investment in these technologies? (fractions of years can be used, if necessary). If your firm has already broken even, please report the actual time to break even.

12. Think about the total cost of patenting for each of the listed patents. On *average*, what *percentage* of that cost is due to each of the following: (please write a percentage next to each of the following items)

a. obtaining and retaining the patent grant (including the cost of drafting the patent application, patent office fees, renewal fees, and other legal fees)?
b. enforcing the patent against infringers?
c. defending the patent against invalidity challenges or other suits?
d. Research and development costs?

13. If the cost of patent enforcement and defence of these patents against actions by others were to rise by 10%, what would be the *percentage* change in your R&D expenditure?

_____ 0%

_____ 25% reduction	_____ 25% increase
_____ 50% reduction	_____ 50% increase
_____ 75% reduction	_____ 75% increase
_____ 100% reduction	_____ 100% increase
	_____>100% increase

14. Would a change in the cost of enforcement induce you to do more (circle as appropriate):

licensing out? (yes/no) licensing in? (yes/no)

15. When an enforcement issues arises regarding a patent, rank the following strategies in order of their importance in avoiding litigation (write number, with "1" being the most important, next to each item)

- Cross licensing
- Licensing (either licensing out one of your patents or licensing in a patent of the other party)
- Other (please specify)_____

16. Of the patents that you license out, what percentage is licensed for:

____% up-front payment only
____% royalty only
____% royalty and up-front payment
____% other fee structure (please specify)

17. Of the patents that you license out, what percentage is licensed *exclusively?* _____%

18. If you have licensed any of these patents, what *percentage* of the total profits (including any spillover profits for your other products) of the innovation have you attempted to recover through the licensing fee structure?

_____ 0%
_____ 25%
_____ 50%
_____ 75%
_____ 100%

19. Which of these patents has been subject to regulatory procedures (such as health and safety approval) beyond patenting? Please write the patent numbers below:

Please draw a diagram of the regulatory procedure(s) or describe these procedures in words in the space below:

20. If your patent(s) have been subject to regulatory procedures beyond patenting, by what percent have the *direct costs* of procedures reduced the profits due to the patent(s), *on average*?

    _____ 0%
    _____ 25%
    _____ 50%
    _____ 75%
    _____ 100%

21. What was the *average* increase in time to market for your patented product due to:

a. the patent process? _____ days/months/years (cross out as relevant)
b. other regulatory procedures? _____ days/months/years (cross out as relevant)

22. By what *percentage* did the cost of obtaining regulatory approval fall after using the approval procedure once? _____ twice? _____

23. If the cost of regulatory approval (beyond patenting) were to rise by 10% for these patents, what would be the *percentage* change in your licensing activity?

_____% change licensing in _____% change licensing out

24. Consider the products that you produce with these patents. *On average,* if you were to increase the price of those products by 10%, what percentage (measured in units) of your sales would you lose?

_____ 0%
_____ 25%
_____ 50%
_____ 75%
_____ 100%

25. If your patents benefit purchasers by reducing their costs, *on average,* by what *percentage* do their costs fall (gross of any royalties) as a result of your innovation(s)?

_____ 0%
_____ 25%
_____ 50%
_____ 75%
_____ 100%

26. How many firms do you view as *important* product market competitors for products based on these patents? *(write a number in the space below)*

If possible, give the names of those competitors you view as *important*:

27. How many firms do you view as *important* competitors in research and development in the field of the patents listed above? *(write a number in the space below)*

If possible, give the names of those competitors you view as *important*:

28. Would you classify your firm as still active in the research area of these patents?

Appendix B: Patent Database Methodology

- We used the US and European patent office databases to identify any private or public entity that held a patent that could be used in the area of GM food up to and including year 2000. We then assembled a database with contact information on each of these entities. Each entity was contacted by telephone or by email, and a person who would be capable of answering the survey (and willing to participate) was identified. If the questions in the survey were best completed by more than one individual, for example the patent portion might best be completed by an intellectual property lawyer from the legal department whereas the research questions might best be fielded by a person in the research department, this was allowed. If the entity agreed to participate in the survey, a survey was sent either by email or by the post. After receipt of the survey, the person who had agreed to fill it out was re-contacted (sometimes several times) in order to remind him or her to fill out the survey, supply duplicate copies in case the survey was misplaced and otherwise support the person who was completing the survey. The research assistant for the project performed all the contact, mailing, encoding and follow-up activities.

- The survey consisted of two parts. One part elicited general information about the organisation, including ownership information, headquarter information, size and so on. The second part was a series of twenty-eight detailed questions regarding the strategy undertaken by the organisation in generating and managing the intellectual property resulting from the GM research. The questions included a section asking about the effect of GM regulation on the research conducted by the organisation. Questions aimed at obtaining both qualitative and quantitative information.

- The data in the surveys has been encoded in an Excel spreadsheet.