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AGRIBUSINESS CONCENTRATION, INTELLECTUAL PROPERTY, AND THE PROSPECTS FOR RURAL ECONOMIC BENEFITS FROM THE EMERGING BIOFUEL ECONOMY*

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ABSTRACT
United States policy makers are promoting bio-fuels as an economic development opportunity, especially for rural America. A USDA study claims that developments in energy production from biomass could increase profits for agricultural commodity producers. However, as William Heffernan and his colleagues have demonstrated, concentration in the agrifood sector limits the economic benefits going to the commodity producers. Relying on Heffernan's framework, we compare the distribution of intellectual property of corn and other genetically modified crops with that of the emerging biomass technologies. We find that patent ownership in the emerging biofuel sector is not yet as concentrated as in the agricultural biotechnology sector. However, theories of private ordering predict concentration and our data indicate that concentration is occurring. The results suggest that rural biomass producers are unlikely to gain broad economic benefits from the biofuel economy.

Proponents of the emerging biofuel economy often emphasize one or more of three potential benefits: environmentally friendly energy sources, greater national energy independence, and rural economic development (see Coleman and Stanturf 2006; De La Torre Ugarte et al. 2003; Doornbosch and Steenblik 2007; Sexton and Zilberman 2008). Many factors may influence the likelihood that these benefits will be realized. This paper considers some factors that may limit the achievement of broad economic benefits.

Experts contend that biofuel processing facilities should be geographically diffuse and locally owned to promote broader environmental and economic benefits (Coleman and Stanturf 2006; Meyer 2008; Swenson and Eathington 2006). The reasoning behind such claims is that, due to the bulkiness of the biomass feedstocks, energy efficiencies are lost during transportation to distant processing facilities. Ideally, then, biomass would be processed into fuel closer to the areas where the

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biomass is harvested. Furthermore, the economic benefits in job creation and profit distribution would likely be enhanced when those diffuse production facilities are locally owned.

The development of new technologies is another significant factor in determining potential benefits from biofuels. Pimentel and Patzek (2005) observe that the amount of fossil fuel energy used to produce corn ethanol and soy and sunflower biodiesel is higher than the energy extracted. They also present evidence that ethanol derived from switchgrass and wood "result in a negative energy return" (Pimentel and Patzek 2005:70). Searchinger et al. (2008) are also skeptical of the environmental benefits, pointing out that adding more land to crop production would increase overall carbon emissions. Corn ethanol, for example, would nearly double greenhouse gas emissions over three decades. Searchinger et al. (2008) also contend that carbon savings from switchgrass would not occur for four decades.

Such critical assessments of the viability of biofuels are often based on existing technologies. The emerging biomass sources expected to replace corn are being developed during a period of dynamic research and technological developments. Switchgrass, hybrid poplar, and willow are examples of new biomass sources, which can be genetically modified to enhance the efficiency of the ethanol conversion process. New processing technologies are also being developed. Because of the reliance on high-technology developments, these emerging technologies are often called "second-generation biofuels" (Dornbosch and Steenblik 2007). Since many of these technologies have yet to be fully realized, industry analysts state that they "do not expect any significant cellulosic ethanol production to occur before 2010," but they still claim that research indicates it is a promising new technology (Larson, Pichel, and Rusch 2006:50).

Because the new raw materials are expected to be raised in traditional farming and forest plantation contexts, experts predict economic benefits for rural America. They base this prediction on the simple assumption of a competitive marketplace in which prices are set by supply and demand. According to textbook economics (e.g., Schiller 1996), as demand for some thing increases in a competitive marketplace, the price is likely to rise until supply increases to meet the demand. For example, Sexton and Zilberman (2008) assert the production of biofuels will create additional demands for crop production (see also De La Torre Ugarte et al. 2003; Doornbosch and Steenblik 2007). There is evidence that farmers have been benefitting from the rise of biofuel production. Government mandates for more ethanol production and other food demands have led to dramatically higher crop prices for farmers (Beaubien 2008). However, there are reasons to doubt that this will continue.

The key assumption behind predictions of economic benefits for biofuel raw material producers is that markets are competitive. Though few would argue that markets ever reflect "perfect competition," economic textbooks often recognize degrees of "imperfect competition" (Schiller 1996:120). In the agrifood system, however, calling markets imperfectly competitive may even be misleading.

Agricultural commodities are produced, processed, and eventually distributed to consumers through a series of transactions that social scientists often call commodity value chains (McMichael 2008). Value chain is an appropriate label because each link in the chain represents a market transaction where supply and demand is assumed to determine the price. However, Heffernan (2000) and others (Glenna 2003; McMichael 2008) have argued that large agribusinesses have gained monopolistic and oligopolistic economic control of markets at various links in the value chains, enabling them to extract profits at the expense of raw material producers.

We believe that comparing market concentration of agricultural commodities to the emerging biofuel sector is reasonable because the raw materials for the biofuel sector are expected to be raised by farmers and private forest owners. The first generation of biofuel raw material crops include corn and, to a lesser extent, soy, sunflower, canola and other crops that are also currently raised as agricultural commodities. The second generation of biofuel raw material crops will consist of cellulosic crops, including switchgrass, hybrid poplar, and willow. One characteristic that connects the first and second generations is biotechnology. Because economic benefits from high-technology industries are often captured by securing intellectual property on emerging technological breakthroughs, a study of the concentration of intellectual property may serve as an indicator of which firms are most likely to benefit economically (Boyd 2003; Enriquez 2001). If a patented technology becomes the definitive choice, the company controlling that technology may secure greater control of the market and extend that control to other links in the commodity chain. Through a comparison of intellectual property holdings of first and second generation biofuel technologies, we can make a prediction of the likely distribution of economic benefits for rural America.

We present a brief overview on agribusiness concentration in the agrifood system and then highlight how the emergence of agricultural biotechnology[1] has enabled concentration of intellectual property in the agrifood system. After presenting a theory on the tendency for intellectual property in high-technology industries to become consolidated so that firms can generate commercial goods and services, we compare the intellectual property holdings of genetically modified (GM) corn, non-corn GM plants, and biofuels. We conclude by describing evidence suggesting that a similar concentration process is occurring in second-wave biofuels and consider the implications for rural economic development.

CONCENTRATION IN AGRICULTURAL COMMODITIES AND RURAL ECONOMIC DEVELOPMENT

As we have already noted, many predictions of rural economic development rest on the assumption of competitive markets. Economists often define a market shifting from competitive to monopolistic or oligopolistic when four or fewer firms gain control of more than 40% of the market (Heffernan 1999).[2] Heffernan (2000) contends that a small group of agribusinesses has achieved oligopolistic control of commodity value chains through the strategies of horizontal and vertical integration. Horizontal integration refers to a small group of companies gaining greater market share of one segment of a commodity chain. Hendrickson and Heffernan (2007) demonstrate that a few large agribusinesses now control many agricultural commodity value chains. For example, four firms control more than 80% of beef packing, more than 60% of pork packing, and 80% of soybean crushing. Just three firms control 55% of flour milling.

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[1] The U.S. Department of Agriculture (USDA) defines agricultural biotechnology as, "A range of tools, including traditional breeding techniques that alter living organisms, or parts of organisms, to make or modify products; improve plants or animals; or develop microorganisms for specific agricultural uses." (See glossary at http://www.fas.usda.gov/itp/biotech/biotech_trade.asp.) Some scientists and USDA officials distinguish "old" biotechnologies (traditional techniques) from "new" ones. New biotechnology refers to genetic modification (GM) of a plant or animal. In this paper, we use agricultural biotechnology to refer to the techniques used to modify crops and the GM crops as the result of using those techniques.

[2] This is comparable to the legal definition of concentration. The U.S. Department of Justice uses the Herfindahl-Hirschman Index (HHI) to calculate market concentration. With this measure, concentration "is calculated by squaring the market share of each firm competing in the market and then summing the results." Markets with and HHI measure between 1000 and 1800 is considered "moderately concentrated." A measure over 1800 is considered to be concentrated. (www.usdoj.gov/atr/public/testimony/hhi.htm Downloaded: 3/27/2009).

Vertical integration refers to a small group of companies gaining control of multiple segments. For example, a few large companies may gain control of grain markets and then expand that control over grain milling, feed production, feedlots, and meat processing (Hendrickson and Heffernan 2007). Farmers selling their commodities in such oligopolistic markets are not likely to get a fair price.

Highlighting the link between market power and political power is also important. During the 1970s and 1980, the enforcement of antitrust regulations in the U.S. was relaxed as regulators sought to "balance the efficiency gains from concentration with the inefficiencies associated with possible anti-competitive behavior…." (Rubinfeld 2001:553). This change was influenced by the Chicago School's "belief that most markets are competitive, even if they contain a relatively few number of firms" (Rubinfeld 2001:556). Some scholars use the term neoliberalism to refer to this belief behind the shift in U.S. public policy (Bonanno 1998; Glenna and Gronski 2008). Heffernan and Constance (1994) credit the weaker enforcement of antitrust regulations with the rise of corporate consolidation in the agrifood system.

This paper focuses particular attention on the emergence of oligopolistic control of seed markets, because much of the intellectual property for technological breakthroughs in the agricultural and biofuel sectors is packaged in plants. As Enriquez (2001:226) has argued, "after engineering a plant's genes, companies had to find a way to distribute their product. Seed companies provided a means for the widespread dispersal of new germ lines." This led chemical and pharmaceutical companies to form agricultural biotechnology firms that, in turn, began purchasing seed companies.

Although biotechnologies that enable specific genetic modification are relatively new, efforts to establish protection for genetic material is an old trend. Kloppenburg (2004:335), for example, argues that the popular narrative of plant breeders in the mid-twentieth century developing hybridized corn to enhance yield is false. He argues, "plant breeders have long pursued hybrids less for their superior agronomic characteristics than for the 'biological patent that they confer'" (Kloppenburg 2004:319). "Biological patent" refers to the fact that hybridization enabled capitalist accumulation in agriculture because it limits the farmers' ability to replant harvested seed. Thus, seed companies could sell seeds to farmers every planting season. The new agricultural biotechnologies and their accompanying intellectual property protections enable the private sector to profit from seed production even in crops lacking that biological patent (Kloppenburg 2004; see also Aoki 2003; Safrin 2007).

Intellectual property protection on new biotechnologies refers to a relatively recent development. The 1980 Supreme Court decision, *Diamond v. Chakrabarty*, permitted the patenting of a synthetic living organism. The decision enabled the patenting of biological and genetic material that was previously considered open access property (Safrin 2007). Though corn varieties have been developed and improved by farmers for millennia, scientists are now able to claim property rights on a corn variety by genetically modifying it (Liptak 2003).

As seeds became the mechanism for agricultural biotechnology firms to deliver their intellectual property to agricultural raw material producers, horizontal consolidation of intellectual property in the agricultural biotechnology sphere gave way to vertical consolidation throughout the agrifood system (Boyd 2003). Hendrickson and Heffernan (2007) cite secondary sources describing how a few companies that had significant holdings of intellectual property began purchasing seed companies. Two companies, DuPont-Pioneer and Monsanto, account for 56% of the U.S. seed corn market (see Fernandez-Cornejo 2004). Globally, four companies account for 29% of the world market in commercial seeds (see UNCTAD 2006). Since Monsanto's seeds account for 90% of the world's genetically modified crop acreage, there is a strong likelihood that they have secured a monopoly (see Davoudi 2006).

These companies then made alliances with other companies to expand their control through vertical integration to achieve what one company described as "farm gate to dinner plate" (Heffernan 1999:7). For example, Cargill became one of the largest seed firms through acquisitions. However, it needed to form a joint venture with Monsanto to gain access to intellectual property of plants. Similarly, Archer Daniels Midland formed an alliance with Novartis (which became Syngenta); as did ConAgra and DuPont-Pioneer (Heffernan 1999). This served to solidify control by a few companies of agricultural inputs and commodity purchasing and processing segments of the agrifood system. The lack of competitive markets means that farmers are likely to pay more for inputs and receive less for their commodities.

Although such consolidation poses long-term economic problems for farmers, they continue to purchase and plant GM seeds. Since the first major GM agricultural crops appeared in 1996, the planting of transgenic crops has expanded dramatically. In the United States, adoption of herbicide tolerant (Ht) soybeans reached 92% of the soybean acreage in 2008. Ht cotton was planted on 68% of cotton acreage and Ht corn on 63% in 2008. Insect-resistant crops with the Bt gene were also adopted widely. Farmers planted Bt cotton on 63% of cotton acreage and Bt corn on 57% of corn acreage in 2008 (Fernandez-Cornejo 2009).

In 2007, for the twelfth consecutive year, the global area of genetically modified crops continued to expand rapidly, reaching 282.4 million acres. The number of countries planting GM crops is currently 23, including 12 developing countries (James 2007). Enriquez (2001:227) argues that "farmers found that even though the new seeds were more expensive and sometimes required very restrictive agreements as to how they should be planted, they did provide significant improvements in overall yield and profit." As market concentration continues, however, farmers will likely find diminishing benefits.

The case of Monsanto's Roundup-Ready seeds illustrates how powerful intellectual property rights can affect the interests of farmers. Monsanto (and similarly situated companies) have a great interest in protecting the innovation embodied in each seed. For Roundup, this is a genetic modification that makes the plant resistant to the herbicide, permitting more precise weed control. Protecting this technology is not easy, since every seed is a copy machine that can duplicate the modification. Therefore, a farmer could avoid purchasing more seed the next year by saving some harvest for future planting. To protect its interests, Monsanto uses a "bag tag" license that prevents farmers from saving seed in subsequent years. To date, Monsanto has been successful in enforcing its license against individual farmers (Liptak 2003). In doing so, arguably, it has undermined the tradition of seed saving and changed the relationship between farmers and seed companies (Aoki 2003; Safrin 2007).

The question is whether such concentration in the seed sector will emerge in the biofuel sector. There are several reasons that comparing concentration in the agrifood and biofuel sectors is appropriate. First, like the agrifood sector, there is consolidation in parts of the energy sector. Policy makers and proponents of self-regulating energy markets claimed that deregulation of the energy sector would yield more competition and lower energy prices. However, Blumsack, Apt, and Lave (2006) find no evidence of consumer or systemic benefits from restructuring. As economist Kenneth Rose put it, deregulation "hasn't panned out the way we had hoped" (Davidson 2007:B1). Second, both agricultural crops and biofuel crops are based in biotechnology. An important aspect of that biotechnological scientific research is the generation of intellectual property (Cahoy and Glenna 2009).

In agricultural biotechnology and the biofuel sector, individual scientists and engineers, universities, small start-up companies, and large firms invest substantial research money into making advances in their technological field. They often secure intellectual property in the process, most commonly through patent protection, which enables them to charge licensing fees for their inventions. "The holder of a patent has the legal right to prevent anyone else from making, using, selling, or importing an object or devise that incorporates any feature covered by the specified claims" (Jaffe and Lerner 2004:26). Inventors are thereby able to profit from their investment of resources and ingenuity by preventing others from using their inventions without first paying for the rights to use them.

According to the theory of private ordering, then, companies need to secure some consolidation of intellectual property to bring a product to market (Cahoy and Glenna 2009). However, although such intellectual property assignments provide control over a specific technology, the entire sector within which that technology is applied does not necessarily become monopolized. For example, although the creation of hybridized corn created a biological patent, many more seed corn dealers existed through the 1970s and 1980s than exist today (Boyd 2003; Enriquez 2001; Kloppenburg 2004). With soybean seeds, the top four firms controlled only 5% of the seed market in 1980, just more than 40% in 1989, and more than 55% in 2007 (Shi and Chavas 2009). Therefore, the market was more competitive in 1980 than in 2007. Seed markets were more competitive before the emergence of agricultural biotechnology ushered in a rush by large agricultural chemical and pharmaceutical companies to purchase seed companies.

Furthermore, consolidation of intellectual property does not necessarily have to lead to vertical integration throughout a commodity chain. Although the agrifood sector is characterized by horizontal and vertical integration by a few large agribusinesses, it is conceivable that private ordering of intellectual property in the biofuel sector could coexist with more competitive markets in a broader biofuel sector.

Intellectual property concentration in first-generation biofuel feedstocks already mirrors concentration in agricultural biotechnology because GM corn is the most common plant in both. However, second-wave biofuels are in the research and development phase. Since the second-wave biofuels markets are still emerging, economic benefits still have the potential to be distributed widely.

To compare relative concentration of the agricultural biotechnology sector and the second-wave biofuel sector, we drew data from the US Patent and Trademark Office. We developed four hypotheses to guide our analysis.

- Hypothesis 1: Since the first agricultural biotechnology patent was assigned, many companies have secured ownership of agricultural biotechnology patents.

- Hypothesis 2: As of 2008, agricultural biotechnology patents reflect concentration of ownership.
- Hypothesis 3: Since the first second-wave biofuel patent was assigned, many companies have secured ownership of biofuel patents.
- Hypothesis 4: As of 2008, second-wave biofuel patents reflect concentration of ownership.

After analyzing the data, we offer a brief discussion of tendencies in the ordering of intellectual property in high-technology sectors and consider the implications of these tendencies for the distribution of economic benefits for biomass producers.

DATA AND METHOD

Data for this paper were derived from the U.S. Patent and Trademark Office (USPTO) patents database.[3] We divided the data into three categories: GM corn plants, GM non-corn plants, and biofuel technologies. As noted above, comparing agricultural biotechnology patents with biofuel patents is reasonable because there are similarities in the science behind the technologies, in the application of the technologies as a raw materials produced on croplands and forestlands, and in the types of companies involved. We divided GM corn and GM non-corn plants because corn was one of the first crops to be genetically modified and many patents have been granted to discoveries based in corn research. Furthermore, corn is a significant crop in first-generation biofuels. Therefore, to avoid overlapping between GM corn and other GM plants, as well as overlaps between GM corn and biofuels more generally, we treated GM corn as an independent category.

We generated the list of GM corn patents using classification 800, subclassification 300.1 as a search term (Patents directed to Multicellular Living Organisms and Unmodified Parts Thereof and Related Processes: Herbicide resistant plant which is transgenic or mutant, and the plant is maize). To get the list of non-corn GM patents, we sought patents identified using classification 800, subclassification 300 as a search term (Patents directed to Multicellular Living Organisms and Unmodified Parts Thereof and Related Processes: Herbicide resistant plant which is transgenic or mutant). We chose these two databases because the contents—patents directed to plants that have been genetically modified for herbicide resistance—are specific to agricultural biotechnology and are unlikely to be contaminated with patents related to other industries. For example,

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[3] http://patft.uspto.gov/netahtml/PTO/search-adv.htm

research on crops to generate pharmaceutical uses would be unlikely to be located here.

To get a broad representation of the patents related to cellulosic ethanol production, we accessed the USPTO issued patents database and used a search string designed to identify all patents containing relevant terms that resided in plant and microorganism classes: "(ccl/800/$ or ccl/435/$) and ethanol and (lignocellulos$ or cellulos$) and (fuel or fuels)." All the patents in the resulting group were individually reviewed to determine actual relevance, and unrelated patents were discarded. In addition, we compared the search results with an independent survey of the biofuel patent environment appearing in each issue of the publication, *Biofuels, Bioproducts and Biorefining* to ensure that the essential patents were captured. We acknowledge that the search results may not be a perfect representation of biofuel patenting, as any search likely results in both type I errors (non-biofuel patents included) and type II errors (biofuel patents excluded). However, we remain confident that we have captured a reasonable representation.

Once the lists of patents were identified, we determined patent ownership by examining information on the face of the patent regarding patent ownership. This enabled us to determine the number of discrete owners of the patents. We examined patent assignment data and assembled evidence of joint ventures to determine if ownership of patents is becoming consolidated.

ANALYSIS

Nascent development in high technology fields can be greatly affected by intellectual property environments. As new technological fields move beyond the early stages of development, it is common for many discrete inventors to secure patent protection. Widely dispersed ownership can create what legal academics and economists call "thickets." Thickets occur in an industry when "there is so much overlap among the technologies developed by different companies that it is difficult to bring any product to market without potentially infringing patents held by other companies" (Jaffe and Lerner 2004:59).

The lack of assigned intellectual property rights may promote innovation. Investment in research and development may be seen as worthwhile, because no single company or small set of companies has yet emerged as clear market leader. However, as a technology sector matures, a thicket may emerge from overlapping property rights. These thickets can create obstacles to innovation, because a company or companies may decide that it is unlikely they could piece together diffusely owned patented elements of a technology to create a commercial product.

As Cahoy and Glenna (2009:18) contend, "A single product may need to traverse so many overlapping rights that it requires hundreds if not thousands of licenses for production."

Legal academics and economists refer to the challenge of moving beyond a patent thicket as a "problem of ordering." Many of these scholars consider private ordering to be the ideal solution in a market economy, whereby private firms work independently of direct government intervention to traverse patent barriers. In cases where private ordering is not forthcoming, a commonly held view is that intellectual property rights need to be weakened (Cahoy and Glenna 2009). Cahoy and Glenna (2009) discuss four ways in which private ordering may emerge. The first is vertical consolidation: a company may purchase intellectual property from other companies. The second is joint ventures and cross-licensing: two or more companies may combine intellectual property and expertise to bring a service or product to market. The third way, patent pooling, refers to the usually voluntary creation of a separate entity to provide access to protected information to several companies for a set royalty fee. A fourth approach is standard setting: an industry standard may privilege a particular approach to technological development that is not subject to patent protection or require that any new technological development fit into an existing infrastructure.

The discussion on private ordering is important because it has implications for the distribution of economic benefits along a technological value chain. The goal of distributing economic benefits may create a dilemma from a policy perspective. Private ordering refers to efforts by one or more companies to secure overlapping property rights. A commonly held view regarding private ordering is that it may be necessary for a single firm or a few companies to gain concentrated control over a new technological field for new technologies to emerge (Cahoy and Glenna 2009). To determine if private ordering is occurring, documenting consolidation of diffuse intellectual properties held by many companies into intellectual properties held by a few companies is necessary. We analyzed the data to determine number of patents and number of discrete patent owners. We then examined the mergers and joint ventures (private ordering) that led to the consolidation of ownership of patents that we originally owned by smaller companies.

There are 37 discrete owners of the 525 GM corn patents and 118 discrete owners of the 1013 GM non-corn patents (see Table 1). If the analysis were to stop there, the conclusion might be that there are multiple companies with intellectual property holdings of GM agricultural plants. However, a closer analysis of changing ownership, due to mergers and joint ventures, indicates that the top three firms in the GM corn category control 85.0% of the patents, and the top 3 firms in the GM non-corn category control 69.6% of patents. Using the definition of an oligopoly as four or fewer firms controlling more than 40% of a market, we would argue that there is evidence to suggest that an oligopoly has emerged in GM plants.[4]

Table 1. Comparison of Patent Ownership in Three Segments of Agricultural Biotechnology.

	Corn GM Plants	Non-Corn GM Plants	Biofuel Technologies
Number of Patents.	525	1013	239
Number of Discrete Patent Owners.	37	118	77
Percent Ownership by Top 3 Firms.	85.0%	69.6%	33.5%

Evidence of the process that generated private ordering in the GM corn and GM non-corn patent categories exist in the list of owners of the intellectual property (see Table 2). When 34 discrete firms and universities own the 417 GM corn plant patents and 114 discrete firms and universities own the 833 GM non-corn plant patents, there is compelling evidence of a need for consolidation to bring a product to market. Here, it is likely that large biotechnology agribusinesses consolidated their intellectual property holdings by securing ownership rights from other companies. In GM corn plants, DuPont-Pioneer now controls approximately 40%, Monsanto 37%, and Syngenta 10%. In non-corn GM plants, Monsanto now controls approximately 40%, Pioneer 20%, and Syngenta 10%. To put it more simply, these large companies overcame patent thickets by investing resources to either purchase companies or form joint ventures with them to assemble the intellectual property necessary to create a commercial product.

Concentrated ownership of patents does not guarantee concentrated market power or vertical integration of other segments of the market. However, for GM corn and GM non-corn plants, concentrated ownership of intellectual property coincided with the emergence of horizontal and vertical consolidation of market power (Boyd 2003; Enriquez 2001; Hendrickson and Heffernan 2007). Furthermore, as Heffernan et al.'s (1999) discussion on the formation of agrifood clusters (e.g.,

[4] An HHI analysis would be needed to determine if consolidation in this market met the DOJ's definition of oligopoly.

Monsanto/Cargill) indicates, these companies also used joint ventures and purchases to integrate vertically.

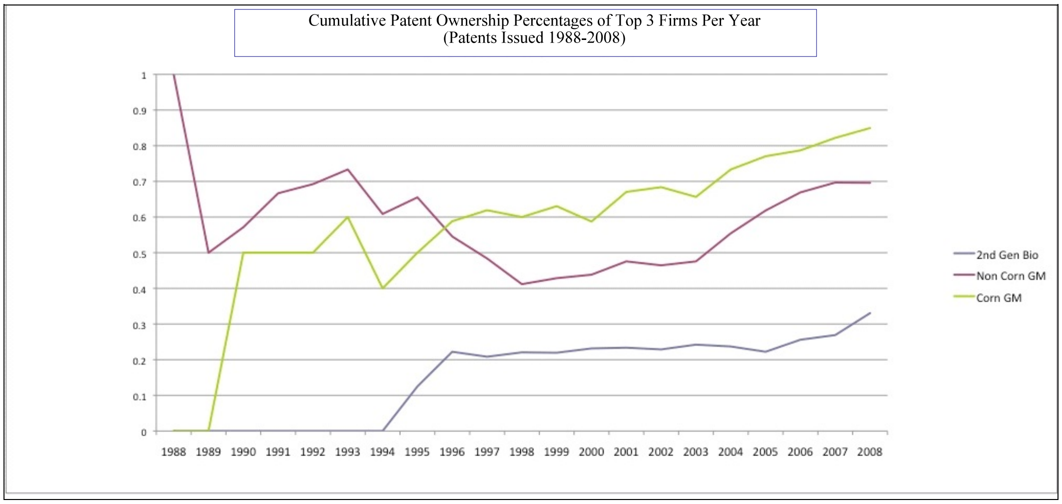
Table 2. PATENT OWNERSHIP CONSOLIDATION

Monsanto	Asgrow, Stine Seeds (shared), Delta Pine, Seminis, Calgene, Emergent Genetics, Agracetus, Dekalb, Holden's Foundation, MGI Pharma, First Line
Pioneer Hi-Bred	DuPont, Hybrinova, Mertec, EvoGene, Bigemma
Bayer Crop Sci	Aventis, Rhone Poulenc Rhorer, Hoescht, Schering, AgrEvo, Plant Genetic Systems
Syngenta	Novartis, Ciba-Geigy, Sandoz, Advanta, Garst, Northrup King, Mogen, Zeneca, J.C. Robinson, Golden Harvest
Dow	Cargill, Agrigentics, Mycogen, Illinois Foundation
Limagrain	Soygenetics, Harris Moran
BASF	American Cyanamid
Danisco	Genencor, Xyrofin
Verenium	Diversa, Celunol

When we apply the same approach to analyzing the biofuel sector, we find that oligopolistic concentration of intellectual property has yet to emerge (see Table 1). Currently, 77 discrete firms and universities own 239 patents, and the top 3 firms own 33.5%. Although this is a substantial level of consolidation, it is not yet as concentrated as GM corn patents or GM non-corn plant patents. However, there is evidence that private ordering, which would likely lead to consolidation, is already emerging in the biofuel sector. Private ordering through horizontal integration and joint ventures is evident in the fact that Danisco has secured the patents of Genencor and Xyrofin, and Verenium has secured the patents of Diversa and Celunol. This suggests that these companies are consolidating intellectual property portfolios.

We also compare change in concentration of patents in GM corn, non-GM corn, and biofuel technologies (See Chart 1). In each case, concentration drops when new patents are assigned to new discrete patent holders. However, new patents are also assigned to large companies that already hold many patents. Furthermore, those larger companies gain control of patents assigned to smaller firms through joint ventures and other efforts. These processes explain the general trend of increasing concentration in agricultural biotechnologies and second-wave biofuels over time. Concentration of second-wave biofuels is still not above the 40% threshold, at which point some consider the market to no longer be competitive. However, the trend in patent ownership over the past few years has been toward greater concentration, with the three largest companies, Danisco, Novozymes, and Midwest Research, controlling an increasing share.

Chart 1. Patent Ownership by Top 3 Firms over Time



The biofuel sector is still in an early stage of research and development. As significant technological breakthroughs continue, there is a high probability that the top firms in the biofuel sector will begin to mirror the patent ownership pattern in the agricultural biotechnology sector. Our data indicates that biofuel companies are moving in the direction of horizontal integration of intellectual property. These new technologies will need to be implemented in a commodity chain that includes production, collection and transportation, and processing of biomass, similar to the agrifood system. A likely strategy will be to vertically integrate into clusters with large agribusinesses like Archer Daniels Midland or Cargill, just as agricultural biotechnology firms did.

CONCLUSION

In their explanation of why deregulation of the energy sector failed to yield benefits to consumers, Blumsack et al. (2006:16) contend that "Deregulation became the end, rather than a means, of benefiting society." They note that there are many policy options available for restructuring that market, which could distribute economic benefits more broadly. However, policy makers did not adopt these approaches because they held a "blind faith" in markets to self regulate. When markets are restructured to allow private entities to manage affairs without direct government intervention, they still require close monitoring and interventions to punish violators (Blumsack et al. 2006). Yet monitoring and government interventions are the first casualties of deregulation efforts, since proponents of deregulation often pledge their allegiance to self-regulating markets. By this logic, there is no need for government oversight.

Whether it is ideology, corporate power over the political process, some combination of the two, or lack of awareness of the issues, policy makers have devoted insufficient attention to the ways that corporate consolidation might affect the distribution of economic benefits of the biofuel economy for rural America. It is not surprising that policy makers are eager to promote biofuels as a solution to economic problems for farmers and for rural America. Dramatic changes in the agriculture and food system have led social scientists to speculate on the end of farming as a family livelihood strategy (Labao and Meyer 2001). Since biofuels have the potential to lead to higher prices for farm and forestry biomass production, policy makers may foresee that promoting the biofuel economy will at least slow the continuing decline of farming as a family livelihood strategy.

However, in the current policy climate, private ordering of innovations in high technology areas often bring tradeoffs. Since profit margins are so narrow, companies may see horizontal integration as necessary to justify investment in research and development. If companies such as Monsanto, DuPont, and Syngenta had not succeeded in consolidating their intellectual property, they might have lacked adequate incentives to invest in agricultural biotechnology research and development. For example, because Monsanto could pursue private ordering through joint ventures and consolidation, its investment in the creation of herbicide-tolerant and pesticide-producing crops led to innovations that have introduced more benign herbicides and a reduction in pesticide applications. Thus, there were some environmental benefits. However, that process of private ordering also led to the formation of vertically integrated oligopolistic agricultural markets, which has had negative economic impacts on the farm economy.

Whether such tradeoffs will emerge in the biofuel sector remains an open question. Biofuels may provide an opportunity for rural development so long as the primary benefits will accrue to farmers and forest landowners, to small businesses that might stimulate job growth, and to rural communities (to the extent that an influx of money will enhance the rural service sector). Since the future of this important technology resides in cutting edge research and development advances, assuming that patents will play an important role is reasonable. An overview of the current patent ownership landscape suggests that the biofuel patent environment is diverse and fractioned. However, using GM crops as a guiding heuristic, we predict that a pattern of consolidation that has characterized GM crops since the 1990s may emerge in the biofuel sector. Policy makers could conceivably intervene to enable private ordering of intellectual property, but limit the vertical integration of that market power into other market segments, such as biomass transport and processing. However, if large agribusinesses consolidate control of the intellectual property, it is unlikely that the predicted economic benefits for rural America will emerge. Although the biofuel technology patents are not currently as concentrated as GM crop patents, our analysis suggests that greater consolidation is likely to emerge. Policy makers would need to engage in the kind of complex and pragmatic policy approaches discussed by Blumsack et al. (2006) to balance the interests of companies investing in biofuel research and development with the interests of the biomass producers. Since that has yet to happen, the initial positive economic benefits of increased agricultural commodity prices may be replaced by lower prices in less competitive markets for biofuel raw materials.

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