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PRIVATE ORDERING AND PUBLIC ENERGY INNOVATION POLICY

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ABSTRACT

Nascent development in alternative energy technologies can be greatly affected by intellectual property environments. Tight control over foundational patent rights by a few companies can hold up commercialization. Conversely, widely dispersed ownership can create thickets that discourage innovation investment ex ante. Given the high-technology nature of the most promising alternative energy proposals, such intellectual property impacts are of great concern. This Article considers the issue in the specific context of the most widely used alternative fuel source—ethanol-based biofuels. It finds that the ownership environment is quite diverse and theoretically ripe for a so-called anticommons effect. However, using analogies to general agricultural biotechnology, this Article demonstrates that the biofuel patent environment is likely to undergo a striking transformation through the effects of private ordering. It articulates a general model of ordering behavior and suggests the most important conditions that facilitate ordering in particular industries. This Article concludes that market-based reordering of patent ownership, although not without negatives, may promote efficient commercialization and blunt the need for government intervention in certain alternative energies. It should be factored into any rational public energy policy.

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I. INTRODUCTION

In recent years, the global community has expressed increasing concern regarding the availability of future energy supplies. If oil production peaks in the near future, as some suggest,[1] subsequent supply will fail to meet demand. The emergence of China and India as major consumers places even greater constraints on energy markets.[2] To be sure, the current economic downturn has temporarily relieved some of the pressure,[3] but energy-producing states have been laboring to support prices,[4] and the failure to pursue expanded production may lead to a severe shortage when the economy recovers.[5] In addition to supply issues, current energy sources produce significant levels of greenhouse gases that are now widely believed to be contributing to a global warming trend.[6] Moreover, many energy re-

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1. The notion of peak oil was discussed extensively in a 2005 report sponsored by the U.S. Department of Energy. ROBERT L. HIRSCH ET AL., PEAKING OF WORLD OIL PRODUCTION: IMPACTS, MITIGATION, & RISK MANAGEMENT (2005). Predictions of when it will occur differ significantly. *Id.* at 17-19. U.S. oil production peaked some time ago in the early 1970s. *Id.* at 16.

2. *Id.* at 55. *See generally* INTERNATIONAL ENERGY AGENCY (IEA), WORLD ENERGY OUTLOOK 2007: CHINA AND INDIA INSIGHTS (2007).

3. *See* IEA, OIL MARKET REPORT 4 (2009) [hereinafter IEA-OMR] (forecasting that as a result of the economic crisis and conservation in response to high prices in the summer of 2008, world oil use will fall for the first time since the early 1980s).

4. *See* Brian Baskin, *Oil Ends at $45.38, a Five-Week High*, WALL ST. J., Mar. 5, 2009, at C12 ("The draw indicates that the Organization of Petroleum Exporting Countries has met with some success in reducing production to match demand weakened by the global economic downturn."); Spencer Swartz & Neil King, Jr., *OPEC Cuts 1.5 Million Barrels from Daily Output; Cartel's Move to Slash 2% of World Demand Lacks Immediate Impact; Oil Price Drops to Lowest Level Since May 2007*, WALL ST. J., Oct. 25, 2008, at A6 (describing the oil producing cartel's attempt to shore up prices in the midst of economic decline).

5. According to the IEA, curbed investment and inadequate new supply in the face of a global recovery "could sow the seed of a sudden reversion to much higher prices, and further intense price volatility, . . . with all the adverse impacts on economic growth that this would imply." IEA-OMR, *supra* note 3, at 24.

6. *See* INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE (IPCC), CLIMATE CHANGE 2007: SYNTHESIS REPORT 36-41 (2007).

sources, particularly oil, are in the hands of unstable governments that appear to pose an ever greater threat to international security as their pockets are lined with energy profits.[7] Though people may reasonably disagree as to the level of danger posed by any one of these issues, it is fair to say that a cumulative pressure has pushed the global consciousness toward the investigation of alternative fuel sources.

At a glance, biofuels appear to neatly address many of the problems in current energy supplies. They are a source of energy that can be produced in large quantities by any country with advanced agricultural technologies and resources,[8] may be more environmentally friendly than fossil fuels,[9] and could serve as a rural development tool to boot.[10] However, in its current form, biofuel production has produced significant externalities, causing policymakers to look toward the high-tech future of so-called second generation or cellulosic biofuels.[11] In this emerging environment, intellectual property—particularly patents—can be expected to play a significant role. If intellectual property rights provide the expected research and development incentives, the future of biofuel innovation and global energy supplies should be bright.

Unfortunately, there is a cloud on the horizon. In developing industries where dominant players have yet to emerge, overlapping patents may be spread among many competitors, forming a thicket of rights. Second generation biofuels could comport with this model. Michael Heller and Rebecca Eisenberg pointed out several years ago that such an overabundance of rights could act as an anticommons—a state in which no one can commercialize due to the veto power of

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7. COUNCIL ON FOREIGN RELATIONS, NATIONAL SECURITY CONSEQUENCES OF U.S. OIL DEPENDENCY 22-23 (2006).

8. Stephan Herrera, *Bonkers About Biofuels*, 24 NATURE BIOTECHNOLOGY 755, 755 (2006).

9. IEA, WORLD ENERGY OUTLOOK 2006, at 391-93 (2006) [hereinafter 2006 ENERGY OUTLOOK] (discussing the possible positive environmental impact of biofuels but noting that several factors may change this).

10. *See*, *e.g.*, STEVEN E. SEXTON & DAVID ZILBERMAN, BIOFUEL IMPACTS ON CLIMATE CHANGE, THE ENVIRONMENT AND FOOD 17-18 (2008), *available at* http://www.energybiosciencesinstitute.org/index.php?option=com_docman&task=doc_download&gid=13; Ofir D. Rubin et al., *Implied Objectives of U.S. Biofuels Subsidies* 10-17 (Ctr. for Agric. and Rural Dev. at Iowa State Univ., Working Paper 08-WP 459, 2008), *available at* http://www.card.iastate.edu/publications/DBS/PDFFiles/08wp459.pdf (discussing the impact of biofuels on job creation and commodity prices). A viable, long-term industry can funnel profits into small businesses (as well as large agribusinesses). The recent rise in commodity prices has seen the revival of small towns across the Midwest. *See* Jason Beaubien, Morning Edition: Ethanol Demand, Prices Boost Farm Communities (transcript of NPR radio broadcast, Mar. 4, 2008), *available at* http://www.npr.org/templates/story/story.php?storyId=87782087.

11. *See*, *e.g.*, Mark Svenvold, *The Biofuel Race*, N.Y. TIMES MAG., Dec. 9, 2007, http://www.nytimes.com/2007/12/09/magazine/09_7_biofuel.html.

any individual's overlapping patent.[12] Theoretically, an anticommons can slow or completely stall innovation. If this occurs, the hope placed on biofuel energy may be effectively dashed.

This Article considers the issue of patent barriers in alternative energy research and provides new optimism by highlighting an often-overlooked countering effect: private ordering. The ability of firms in some technologies to consolidate patent rights through sales and licensing can significantly reduce holdups, preserving the pace of innovation. To explore the private ordering phenomenon, this Article first provides context in Part II by articulating the connection between patents and emerging technologies. The problem of building block patents as well as patent thickets is addressed. Next, in Part III, the Article describes the effect of private ordering, drawing an analogy to agricultural biotechnology. Positive mechanisms of private ordering behaviors are provided and the necessary conditions for ordering are described. Finally, in Part IV, the Article provides an outline for integrating the reality of private ordering into energy policy. It suggests tools for avoiding market failures with information rather than regulation, but it also cautions as to the broader social implications of consolidation, which may be quite negative. The road to energy security is littered with ill-considered policy choices, the Article concludes, but the situation is now much more critical. Failing to consider the behavior of the private market would be a serious misstep in the search for a solution so desperately needed.

II. PATENT CHAOS AND ENERGY INNOVATION

The recent emphasis on alternative energy sources has brought biofuels like ethanol to the forefront of the debate. Despite their rather low-tech heritage, future biofuel sources are grounded in cutting-edge research. The positive impact of private patent rights on innovation in research-intensive fields is an essential presumption of the intellectual property system. But the reality is that patent rights can serve as innovation barriers in some instances. Nascent fields like second-generation biofuels may be especially susceptible. In view of these concerns, it would be logical to conclude that government intervention is necessary to preserve optimal levels of invention and commercialization.

A. *From the Farm to the Lab: Biofuel's Future in High Technology*

Biofuel is often discussed as a future, exotic fuel source in the United States, but it has actually been in wide use for many years

12. Michael Heller & Rebecca Eisenberg, *Can Patents Deter Innovation? The Anticommons in Biomedical Research*, 280 SCIENCE 698, 698-99 (1998).

and is the leading source of renewable energy.[13] In fact, the United States is a world leader in biofuel production.[14] The most basic and commonly used biofuel is ethanol.[15] Ethanol is derived primarily from farmed feedstocks (as opposed to lab-grown cell cultures) and can power just about any type of mechanical device, provide heat, and supply electricity. Interestingly, the technology for producing large quantities of ethanol from feedstocks like corn and sugar cane[16] is not dramatically different from the methods that have been used for thousands of years to produce alcoholic beverages.[17] It is generally viewed in the short term as a replacement for fossil-based automobile fuels like gasoline and diesel,[18] but it may have additional long-term uses. Another common biofuel is "biodiesel," a high-energy oil product that can be derived from biomass waste products or even used food oil.[19] Because it requires a significant conversion of existing automobile engine technology for use in gasoline-powered engines, it has not received as much attention and constitutes only about ten percent of the world's biofuel production.[20]

However, existing biofuel technology has important limitations that make it far less viable as future fuel source, at least in its present form. One limitation is the amount of greenhouse gasses released by the production of bioethanol from corn. When the fuel for farm machinery and electricity for production facilities (both of which

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13. According to the U.S. Energy Information Administration (EIA), biomass constituted fifty-three percent of the energy consumption from renewable sources, edging out hydroelectric at thirty-six percent. EIA, RENEWABLE ENERGY TRENDS IN CONSUMPTION AND ELECTRICITY 2007, at 1 (2009), *available at* http://www.eia.doe.gov/cneaf/solar.renewables/page/trends/trends.pdf.

14. 2006 ENERGY OUTLOOK, *supra* note 9, at 387 (noting that the United States was predicted to overtake Brazil in biofuel production by 2006).

15. Daniel M. Kammen et al., *Energy and Greenhouse Impacts of Biofuels: A Framework for Analysis*, *in* ORGANIZATION FOR ECONOMIC COOPERATION AND DEVELOPMENT (OECD), BIOFUELS—LINKING SUPPORT TO PERFORMANCE 41, 45 (2008).

16. Practically any sugar or starch containing biomass can be readily employed to make ethanol, and different countries rely on a variety of different crops. For example, Brazil has for years employed a wildly successful program to convert sugar cane into ethanol. 2006 ENERGY OUTLOOK, *supra* note 9, at 387. The country even exports surplus ethanol derived from this high-energy source. *Id.* at 397.

17. After the biomass is collected, it is fermented until the sugar converts to ethanol. *Id.* at 388. That ethanol is then distilled to a more pure form. *Id.* While the machinery has certainly moved into the industrial age—with gigantic bioreactors and fermentors that can produce millions of gallons in a single batch—the technology has more in common with a medieval brewery than modern biotechnology techniques. *See* Richard Doornbosch & Ronald Steenblik, *Biofuels: Is the Cure Worse than the Disease?*, OECD Pub. No. SG/SD/RT(2007)3, at 10 (2007) ("Ethyl alcohol, or ethanol, can be produced from any feedstock that contains relatively dense quantities of sugar or starchy crops, using nothing more than a flask."); *see also* Kammen et al., *supra* note 15, at 46 ("[C]urrent biofuel production processes are many years old.").

18. 2006 ENERGY OUTLOOK, *supra* note 9, at 386-87.

19. *Id.* at 387.

20. *Id.*

are almost always derived from fossil sources) is taken into account, the advantage of biofuels compared to oil is less clear.[21] Some argue that, depending on the processing and the particular biofuel feedstock used, the total amount of greenhouse gasses produced actually represents a net *increase* over fossil fuels.[22] This has obvious implications for the global warming rationale for switching to biofuels. Perhaps a greater problem is posed by the current dependence on food-related crops to produce bioethanol.[23] For example, in the United States, corn is by far the most common source of bioethanol. Although humans do not directly ingest the corn used for biofuel production, it is used for farm animal feed.[24] Additionally, it takes up a great deal of land that could otherwise be used for human food crops, with more land being converted to biofuel production each year.[25] This dependence on food crops has led to the suggestion that biofuel production is increasing the price and scarcity of world food sources.[26] In view of these issues, the wave of criticism against current biofuel sources has risen dramatically and quickly, dampening their prospects for the future.

In response, biofuel proponents point to its high-technology future, which could resolve a number of the current problems.[27] These technologies are often termed "second generation" biofuels.[28] Most plant matter, even in conventional biofuel feedstocks, is unsuitable

21. Doornbosch & Steenblik, *supra* note 17, at 17-18 (describing greenhouse gas emissions).

22. *Id.* at 17 ("In some cases, emissions may be as high or higher than the net GHG emissions from gasoline vehicles."); SEXTON & ZILBERMAN, *supra* note 10, at 9-10.

23. Doornbosch & Steenblik, *supra* note 17, at 33-34; John Carey et al., *Food vs. Fuel*, BUS. WK., Feb. 5, 2007, at 80 ("The roughly 5 billion gallons of ethanol made in 2006 by 112 U.S. plants consumed nearly one-fifth of the corn crop. If all the scores of factories under construction or planned go into operation, fuel will gobble up no less than half of the entire corn harvest by 2008.").

24. Doornbosch & Steenblik, *supra* note 17, at 33.

25. *Id.* at 33-34.

26. ORGANISATION FOR ECONOMIC CO-OPERATION AND DEVELOPMENT, FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS [OECD-FAO], AGRICULTURAL OUTLOOK 2008-2017, at 17, 30 (2008) ("[T]he energy security, environmental, and economic benefits of biofuels production based on agricultural commodity feed stocks are at best modest, and sometimes even negative . . . ."); SEXTON & ZILBERMAN, *supra* note 10, at 14-17. According to the USDA, biofuel production has contributed ten percent of the overall increase in food prices in the last year. Lauren Etter, *Probe Sought of Bush Aides' Biofuel Statistics*, WALL ST. J., June 28, 2008, at A2. Some suggest that it may be significantly more when the impact on crops other than corn is taken into account. *See* Andrew Martin, *The Man Who Dared to Question Ethanol*, N.Y. TIMES, July 13, 2008, at BU.5, *available at* http://www.nytimes.com/2008/07/13/business/13feed.html (discussing the research of former USDA economist Keith Collins).

27. Doornbosch & Steenblik, *supra* note 17, at 5. *But see* Elisabeth Rosenthal, *New Trend in Biofuels Has New Risks*, N.Y. TIMES, May 21, 2008, at A6 (stating that some scientists are warning that second generation biofuels may pose problems because the feedstocks are often invasive species).

28. *See*, *e.g.*, Doornbosch & Steenblik, *supra* note 17, at 5.

for current bioethanol production methods because it consists primarily of woody "cellulose" as opposed to sugar or starch.[29] However, it is possible to convert cellulose to either sugar or starch using enzymes or other biotechnology mechanisms.[30] Such conversion opens up an almost limitless supply of biofuel feedstocks from sources that have no relation to the food supply. For example, switchgrass, jatropha, and poplar are prominently mentioned cellulosic feedstocks.[31] Cellulosic waste products from food crops, such as corn stover,[32] could also be converted to ethanol. In addition to a greater variety of biofuel sources, cellulosic feedstocks can be grown on land that is not important for food production.[33] For many, including former President George W. Bush[34] and President Barak Obama, the call is clear to "generate more cellulosic ethanol from agricultural products like corn stocks, switch grass and other crops our farmers grow."[35]

In spite of its clear advantages, cellulosic ethanol is not commercially viable at this time. The expense of converting cellulose to starch or sugar exceeds the energy benefits.[36] Therefore, there is an intense research effort into improving second-generation biofuels. It is generally perceived that a "breakthrough" is required to make cellulosic ethanol a viable option in the future. This breakthrough will likely occur in one of three areas: (1) improved feedstocks, which may include genetically modified plants that provide greater energy stores or resist attack by insect or herbicide; (2) more effective or less expensive enzymes for breaking down cellulose into compounds that can be converted to ethanol; and (3) improved "ethanologens," which are microorganisms that convert substrates into ethanol or other

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29. INT'L ENERGY AGENCY (IEA), ENERGY TECHNOLOGY PERSPECTIVES 2006, at 277 (2006) [hereinafter PERSPECTIVES 2006].

30. *Id.* at 277-79; EIA, *Biofuels in the U.S. Transportation Sector* (Feb. 2007), http://www.eia.doe.gov/oiaf/analysispaper/biomass.html [hereinafter EIA, *Biofuels*].

31. *See* Doornbosch & Steenblik, *supra* note 17, at 11; PERSPECTIVES 2006, *supra* note 29, at 278 ("Fast-growing crops rich in cellulosic components, such as poplar trees and switchgrass, are well suited to produce ethanol.").

32. PERSPECTIVES 2006, *supra* note 29, at 277.

33. Doornbosch & Steenblik, *supra* note 17, at 14.

34. Press Release, The White House, Office of the Press Secretary, President Bush Participates in Panel on Cellulosic Ethanol (Feb. 22, 2007), *available at* http://georgewbush-whitehouse.archives.gov/news/releases/2007/02/20070222-5.html.

35. Barack Obama, Remarks at the Governor's Ethanol Coalition, *Energy Security Is National Security* (Feb. 28, 2006), *available at* http://www.barackobama.com/2006/02/28/energy_security_is_national_se.php; *see also President Barack Obama Holds a News Conference with Regional Reporters*, POL. TRANSCRIPT WIRE, Mar. 13, 2009 ("I've also said . . . that we've got to do a much better job of developing cellulosic ethanol, that corn-based ethanol, over time, is not going to provide us with the energy-efficient solutions that are needed.").

36. Doornbosch & Steenblik, *supra* note 17, at 11; PERSPECTIVES 2006, *supra* note 29, at 278-79 ("Significant technological challenges exist for the production of ethanol from woody feedstocks because all the steps of the production process need to be optimized.").

fuel-related compounds.[37] Research may even bridge these categories, for example, by breeding enzymes into the plants themselves.

The leap forward that is necessary to commercialize cellulosic ethanol will require a great investment of time and money in basic research and development. Any company that makes such an investment will require some protection of its position to assure a return on its investment. This has been traditionally viewed as the role of intellectual property and, in particular, patent rights. For this reason, the intellectual property environment for biofuels may be one of the most important factors in the emergence of economical and efficient cellulosic sources.

B. Patents as a Critical Research Incentive

For many with dreams of profiting from a research breakthrough, patents are viewed as the ultimate tool. They provide their owners with the right to exclude others from most practical applications of the claimed invention.[38] Although patents exist for a relatively short period, particularly when the time to develop and market an invention is taken off the top,[39] they may give a patentee control over key technology at a critical stage, generating great rewards. Conversely, without patent protection, an inventor is left to rely on secrecy to prevent competitors from benefiting from his or her research and development efforts.[40] Public use without any protection may lead to free riding,[41] which actually puts the inventor at a disadvantage vis-à-vis a competitor.

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37. PERSPECTIVES 2006, *supra* note 29, at 278; U.S. DEP'T OF ENERGY, BIOENERGY RESEARCH CENTERS: AN OVERVIEW OF THE SCIENCE 9 (2008), *available at* http://genomicsgtl.energy.gov/centers/brcbrochure_hq.pdf.

38. The U.S. Patent Act gives patent owners the right to exclude others from making, using, selling, or offering to sell the invention in this country, and it gives them the right to exclude others from importing it from another country without the authority of the patent owner. 35 U.S.C. §§ 271(a), 271(e)(4)(B) (2000).

39. *See*, *e.g.*, Daniel. R. Cahoy, *An Incrementalist Approach to Patent Reform Policy*, 9 N.Y.U. J. LEGIS. & PUB. POL'Y 587, 618 (2006) (indicating that although a patent term runs twenty years from the filing date, "[t]he effective patent life is shorter, as time spent prosecuting the application before the relevant patent examining authority comes off the top of the twenty-year term, leaving most patentees with approximately eighteen years").

40. *See* WILLIAM M. LANDES & RICHARD A. POSNER, THE ECONOMIC STRUCTURE OF INTELLECTUAL PROPERTY LAW 294-95 (2003) (arguing that inventors will choose to keep inventions secret if the disclosures accompanying patent protection result in more losses than the exclusivity will provide in gains).

41. *See*, *e.g.*, Kenneth W. Dam, *Some Economic Considerations in the Intellectual Property Protection of Software*, 24 J. LEGAL STUD. 321, 333 (1995) ("The fundamental justification for creating property rights in the results of innovation is to deal with the appropriability problem."); F. Scott Kieff, *Property Rights and Property Rules for Commercializing Inventions*, 85 MINN. L. REV. 697, 717-18 (2001) (discussing Demsetz's description of property rights as a solution to problem of underproduction when the inputs cannot otherwise be fully appropriated). But for a detailed criticism of the potential overuse of the con-

It is asserted that the amount of patenting actually serves as a barometer of research activity.[42] Observing the changes in the patent landscape over time yields a trove of information about who is inventing what and, perhaps more importantly, who is in the position to control the most essential technology. Of course, many other dynamics affect research and development spending, and it has been suggested that the impact of patents differs significantly by industry.[43] For example, because product life span is short in computer-related technologies, the utility of patents is perceived to be very small, and companies generally do not innovate in order to obtain patents.[44] On the other hand, other industries clearly engage in research with a view toward obtaining patents. Biotechnology and pharmaceuticals tend to be at the top of this group, and advocates for each vehemently argue that their success would be all but impossible without strong patent rights.[45]

In predicting the impact of patent rights on next-generation biofuel technologies, it is reasonable to place them in the same category as biotechnology. The anticipated advances are biologic in nature, and the agricultural industry has a robust history of utilizing biotechnology research to increase crop yields, reduce insect infestation, and resist herbicides.[46] This field of "agricultural biotechnology" has

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cept of free riding in justifying intellectual property law, see Mark A. Lemley, *Property, Intellectual Property, and Free Riding*, 83 TEX. L. REV. 1031, 1046-50 (2005).

42. *See, e.g.,* Zvi Griliches, *Patent Statistics as Economic Indicators: A Survey*, 28 J. ECON. LITERATURE 1661, 1701-02 (1990) ("In spite of all the difficulties, patents statistics remain a unique resource for the analysis of the process of technical change."); Jean O. Lanjouw & Mark Schankerman, *Patent Quality and Research Productivity: Measuring Innovation with Multiple Indicators*, 114 ECON. J. 441, 441-43 (2004).

43. *See* Edwin Mansfield, *Patents and Innovation: An Empirical Study,* 32 MGMT. SCI. 173, 174-75, 175 tbl.1 (1986) (surveying dependency on patents in 100 firms in twelve distinct industries).

44. *See*, *e.g.*, Bronwyn H. Hall & Rosemarie Ham Ziedonis, *The Patent Paradox Revisited: An Empirical Study of Patenting in the U.S. Semiconductor Industry*, *1979-1995*, 32 RAND J. ECON. 101, 102 (2001).

45. *See*, *e.g.*, FED. TRADE COMM'N, TO PROMOTE INNOVATION: THE PROPER BALANCE OF COMPETITION AND PATENT LAW AND POLICY ch. 3, at 17-20 (2003) [hereinafter FTC, TO PROMOTE INNOVATION], *available at* http://www.ftc.gov/os/2003/10/innovationrpt.pdf (noting the almost universal recognition of importance of patents in biotechnology industry—"[p]articipants stated that the biotechnology industry would not have emerged 'but for the existence of predictable patents' "); Ashish Arora et al., *R&D and the Patent Premium* 35 (Nat'l Bureau of Econ. Research, Working Paper No. 9431, 2003), *available at* http://www.nber.org/papers/w9431.pdf.

46. *See* JORGE FERNANDEZ-CORNEJO & WILLIAM D. MCBRIDE, U.S. DEP'T OF AGRIC., ADOPTION OF BIOENGINEERED CROPS 4-7 (2002) (detailing the extent of adoption of bioengineered herbicide-tolerant and insect-resistant crops in the U.S.); U.S. DEP'T OF AGRIC., ECON. RESEARCH SERV. (USDA-ERS), ECONOMIC ISSUES IN AGRICULTURAL BIOTECHNOLOGY 3, 10-11 (2001) [hereinafter ECONOMIC ISSUES IN AGRICULTURAL BIOTECHNOLOGY] (providing an overview of several important genetic modifications to crops). *See generally* DANIEL CHARLES, LORDS OF THE HARVEST (2001) (describing the rationale for and implications of the increased use of biotechnology in agriculture).

become extremely important;[47] it is considered a distinct form of biotechnology and has largely taken the place of plant breeding and chemical design in the research programs of large agribusinesses.[48] As with biotechnology, the effort to create patentable advancements is quite resource-intensive. An agribusiness firm's investment in research and development must employ a very forward-looking perspective on its ability to profit from the market, which creates a natural dependence on patent rights, among other mechanisms,[49] to provide for a return on investment.

Interestingly, there is already evidence of increased patenting in biofuels as the energy resource has received more attention from government and industry. Looking simply at patents related to ethanol production from cellulosic biomass, one can see that patent applications have risen significantly in recent years (Figure 1).

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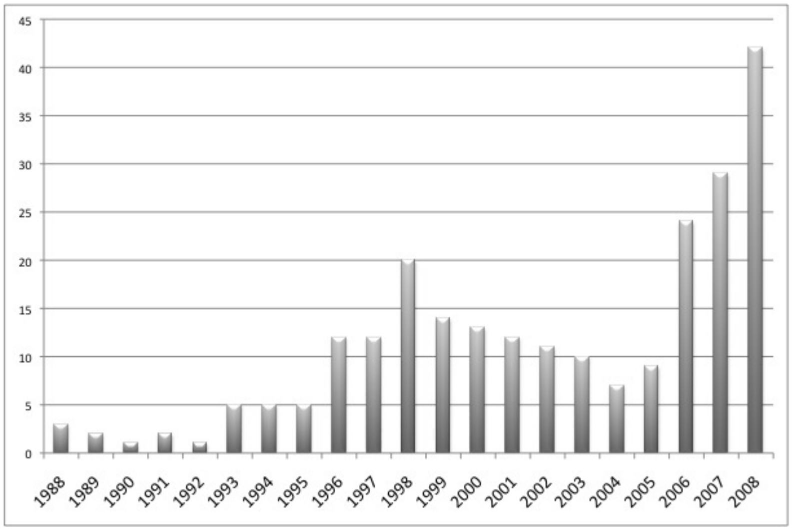
47. ECONOMIC ISSUES IN AGRICULTURAL BIOTECHNOLOGY, *supra* note 46, at 1-2.

48. *Id.* For an excellent account of the struggle for the preeminence of biotechnology in the agricultural industry, see CHARLES, *supra* note 46, at 117-18.

49. An alternative to legal protection is a biological barrier to unauthorized use and propagation. For example, the much discussed genetic use restriction technology (GURT), also known as "terminator technology," serves this function. *See* Richard Caplan, *The Ongoing Debate over Terminator Technology*, 19 GEO. INT'L ENVTL. L. REV. 751, 770-72 (2007); Sergio H. Lence & Dermot J. Hayes, *Technology Fees Versus GURTs in the Presence of Spillovers: World Welfare Impacts*, 8 AGBIOFORUM 172, 173 (2005).

FIGURE 1: PATENTS RELATED TO ETHANOL PRODUCED FROM CELLULOSIC FEEDSTOCKS[50]



Biofuel innovators[51] have clearly responded to the interest in alternate fuels with increased research and development efforts[52] (though the backlash against biofuels may induce a leveling off at some point in the near future).

C. The More Complex Reality of Patents as a Potential Innovation Barrier

The above discussion may lead one to conclude that stronger patent rights automatically lead to more innovation and that greater

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50. To obtain a broad view of the patents related to cellulosic ethanol production, the authors accessed the United States Patent & Trademark Office (USPTO) issued patents database (http://patft.uspto.gov/netahtml/PTO/search-adv.htm) 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, the authors 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. *See, e.g.*, Mara Staffilani et al., *Patent Intelligence*, 2 BIOFUELS, BIOPRODUCTS & BIOREFINING 358, 359-72 (2008). However, the authors readily acknowledge that the search results may not be a perfect representation of biofuel patenting, as any search likely results in both type I errors (nonbiofuel patents included) and type II errors (biofuel patents excluded).

51. Such innovators include recent startups, such as Xethanol, *see* Global Energy Holdings Group, http://xethanol.com (last visited June 1, 2009), and large agribusinesses, such as Monsanto, *see* Press Release, Monsanto, Monsanto Company and Mendel Biotechnology Announce Cellulosic Biofuels Collaboration (Apr. 28, 2008), http://monsanto.mediaroom.com/index.php?s=43&item=596.

52. Patents in the study group were collected through December 2008.

numbers of patents indicate more progress and a greater likelihood of breakthrough innovation in the market. Under these assumptions, one could reasonably conclude that the increasing number of biofuel-related patents is evidence of a robust innovation environment. Inventions and patents, however, do not exist in discrete silos of development and profit, with competitors having only parallel interests. There is often conflict. Patent rights can interact with the innovative efforts of others and actually limit the development of new products and services—or at least add to their expense. Some believe that the barriers can be so high as to require intervention in order to achieve a sufficient level of commercialization of important technologies.[53]

The conflict in innovation environments is due to the intangible nature of intellectual property. Unlike, for example, real property rights, which are linked to a discrete piece of land or fixture upon that land, intellectual property rights are not associated with a particular object. Patents cover ideas that may not even be captured in a physical embodiment.[54] This means that a broad technology field can be impacted in two dimensions. First, patent rights can be so expansive or "foundational" as to cover entire categories of goods or services, regardless of whether the owner actually produces them.[55] Second, it is possible for different rights to impact several aspects of a single technological embodiment, forming a thicket that one must traverse to market without infringing. Under certain market conditions, patent owners may take advantage of such environments to hold up the efficient development of future innovations.

1. Initial Presence of Patent Control over Fundamental Technologies

A building block or foundational patent can be defined as one with claims covering a basic aspect of the technology.[56] It is fundamental

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53. Michael Heller, who in 1998 joined Rebecca Eisenberg in describing the "anticommons," *see* Heller & Eisenberg, *supra* note 12, has recently authored a book that proposes such policy revision. *See* MICHAEL HELLER, THE GRIDLOCK ECONOMY: HOW TOO MUCH OWNERSHIP WRECKS MARKETS, STOPS INNOVATION, AND COSTS LIVES (2008).

54. *See* Pfaff v. Wells Elecs., Inc., 525 U.S. 55, 60 (1998) ("The primary meaning of the word 'invention' in the Patent Act unquestionably refers to the inventor's conception rather than to a physical embodiment of that idea. The statute does not contain any express requirement that an invention must be reduced to practice before it can be patented.").

55. *See*, *e.g.*, Sapna Kumar & Arti Rai, *Synthetic Biology: The Intellectual Property Puzzle*, 85 TEX. L. REV. 1745, 1751 (2007). Some might also call these "pioneering" inventions, and it has been argued that they should be accorded much power in order to encourage innovation. *See* John F. Duffy, *Rethinking the Prospect Theory of Patents*, 71 U. CHI. L. REV. 439, 440-41 (2004) (discussing Edmund Kitch's prospect theory, which would provide substantial power for early-stage innovation, and noting that it has become "a standard part of the law-and-economics literature on patent law").

56. *See*, *e.g.*, Kumar & Rai, *supra* note 55, at 1751 (2007) (characterizing foundational patents as those "with broad claims that appeared important to a large percentage of work in the area").

to the way any specific embodiment will function. Foundational patents need not cover the entirety of important products or services, and they may have been filed long before such embodiments were envisioned. In fact, it is most likely that such patents will cover only a part or aspect of popular products. They may even cover enabling technology that relates to the manufacture or testing of a product but is not embodied in the product itself.[57] Actual participants in the market may not even own them. What is essential is that an entire class of products or services cannot be produced without using the patent and no work-around is readily available. It is essentially impossible to participate in the field without treading on the patent owner's rights.[58] In such cases, the patentee has the power to prevent marketing of the covered products absent authorization.

There are essentially two ways a patent can attain fundamental status. One is that it covers a technology that is so groundbreaking and useful that industry widely accepts it as the base for future innovation.[59] By definition, there is no alternative that will produce the same result. A second is that government or industry groups agree to adopt the covered technology as a standard.[60] In this case, there may be viable alternatives, but adherence to the standard precludes them. Such determinations can be enhanced by network economics, switching costs, or inertia that confer great power on a broad patent covering the standard.[61]

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57. Christopher M. Holman, *Biotechnology's Prescription for Patent Reform,* 5 J. MARSHALL REV. INTELL. PROP. L. 318, 333-34 (2006) (describing the patenting of fundamental enabling technologies in biotechnology, such as the synthesis of artificial antibody molecules).

58. *See* Peter Lee, *The Evolution of Intellectual Infrastructure*, 83 WASH. L. REV. 39, 93 (2008) (describing such patents as part of the "intellectual infrastructure" and arguing that "[a]bsent efficient licensing . . . exclusive rights on this infrastructure may inhibit myriad downstream applications").

59. Mark A. Lemley identifies several of these "building blocks" in fields such as biotechnology, computers, chemistry, and television. Mark A. Lemley, *Patenting Nanotechnology*, 58 STAN. L. REV. 601, 606-14 (2005) [hereinafter Lemley, *Patenting Nanotechnology*].

60. *See* HERBERT HOVENKAMP ET AL., IP AND ANTITRUST: AN ANALYSIS OF ANTITRUST PRINCIPLES APPLIED TO INTELLECTUAL PROPERTY LAW § 35.1a (2002 & Supp. 2008); Mark A. Lemley, *Ten Things to Do About Patent Holdup of Standards (and One* Not *to)*, 48 B.C. L. REV. 149, 154-55 (2007) [hereinafter Lemley, *Ten Things*] (describing how irreversible commitments to standards elevate the power a patent owner has to extract royalties); Philip B. Nelson, *Patent Pools: An Economic Assessment of Current Law and Policy*, 38 RUTGERS L.J. 539, 544-45 (2007) ("The establishment of industry standards, which often takes years to complete, can give market power to individual patents that was not present before the standard-setting process began."); *see also* Mark A. Lemley & David McGowan, *Legal Implications of Network Economic Effects*, 86 CAL. L. REV. 479, 523 (1998) ("To the extent intellectual property rights confer ownership interests in a strong network standard, they may create durable market power in network markets.").

61. *See* Alan Devlin, *A Neo-Chicago Perspective on the Law of Product Tying*, 44 AM. BUS. L.J. 521, 563 (2007) ("A second major feature of modern network industries is that consumers may face significant switching costs in attempting to move from an incumbent firm to a competitor."); Gideon Parchomovsky & Peter Siegelman, *Towards an Integrated*

In the biotechnology field, perhaps the best example of a fundamental technology patent is the one issued for Cohen and Boyer's gene cloning technology.[62] Another good candidate is the patent covering the polymerase chain reaction (PCR) process.[63] Both concepts are essential to modern biotechnology research, and it is hard to imagine any biotech company or academic lab that does not make use of both. In agricultural biotechnology, one can look to the patents on transformation by Agrobacterium—a mechanism for transporting and incorporating genetic material into a plant cell—as a significant foundational technology that reflects a voluntary industry acknowledgment of supremacy.[64] Another example is Monsanto's patent on Roundup® and genetically modified Roundup-Ready® seeds.[65]

At this stage, it is difficult to determine what technologies will be the building blocks of second-generation biofuels. However, given the hope for a breakthrough in efficient cellulosic conversion, it is not unreasonable to imagine that such patents will issue. Additionally, existing technology that is applicable to general agriculture could be just as important to biofuel production. For example, technology for genetically modifying crops or herbicide and insect resistance may play a key role regardless of the specific gene enhancement. To the extent that one form of this technology proves essential in biofuel production, it will be, for all intents and purposes, foundational.

Interestingly, the breadth of a fundamental technology patent can also be an important weakness if it is the result of overclaiming. If a patent is determined to be overbroad in its claims, it can be deemed

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Theory of Intellectual Property, 88 VA. L. REV. 1455, 1476-81 (2002) (modeling switching costs from a patented good in the context of brand loyalty); Jonathan L. Rubin, *Patents, Antitrust, and Rivalry in Standard-Setting*, 38 RUTGERS L.J. 509, 510 n.3 (2007) ("However, given that consensus itself is usually extremely costly—standards often take years to develop—switching costs are almost always present, even if very large investments in implementation have yet to be made.").

62. Process for Producing Biologically Functional Molecular Chimeras, U.S. Patent No. 4,237,224 (filed Jan. 4, 1979) (issued Dec. 2, 1980); *see also* NAT'L RES. COUNCIL, INTELLECTUAL PROPERTY RIGHTS AND THE DISSEMINATION OF RESEARCH TOOLS IN MOLECULAR BIOLOGY 40-42 (1997); Arti K. Rai & Rebecca S. Eisenberg, *Bayh-Dole Reform and the Progress of Biomedicine*, 66 LAW & CONTEMP. PROBS. 289, 300 (2003).

63. Process for Amplifying Nucleic Acid Sequences, U.S. Patent No. 4,683,202 (filed Oct. 25, 1985) (issued July 28, 1987). Mark A. Lemley notes that this patent was widely and successfully licensed but ultimately declared unenforceable due to inequitable conduct. Lemley, *Patenting Nanotechnology*, *supra* note 59, at 611.

64. *See, e.g.*, Holman, *supra* note 57, at 335-36 (describing the significance of the patents to the agricultural biotechnology industry). The ownership of the patented technology was actually a matter of significant legal dispute between four entities—Bayer Crop Science, Max Planck Society, Garching Innovation, and Monsanto—that was apparently resolved only recently. *Id.*; Press Release, Monsanto Co., Bayer Cropscience, Max Planck Society, Monsanto Company Resolve Agrobacterium Patent Dispute (Feb. 4, 2005), http://www.monsanto.co.uk/news/ukshowlib.phtml?uid=8561.

65. Chimeric Genes for Transforming Plant Cells Using Viral Promoters, U.S. Patent No. 5,352,605 (filed Oct. 28, 1993) (issued Oct. 4, 1994).

invalid and essentially disappear.[66] There is an inherent risk in aggressively enforcing such patents. In many cases, a preferable strategy is to tread lightly and license broadly, leaving the right untested in a formal legal proceeding.[67] Several foundational patents in biotechnology have followed this pattern.[68] This creates a de facto limitation on the power of foundational patents.

Another important limitation on fundamental technology patent control is the passage of time. Due to the strict conditions of patentability, such applications generally end up being filed early in the lifespan of the technology.[69] Any attempt to cover a greater breadth of invention following the disclosure of a narrower embodiment would commonly be rejected as anticipated or obvious.[70] And while it is possible for one to file a patent on foundational technology early but wait to bring it to issuance until after the valuable applications become clear, the impact of such efforts will be limited since a patent term is calculated from the filing date.[71] Moreover, one cannot simply extend the power of a broad patent by filing subsequent, related patents based on the original disclosure because the original claimed invention will be available to competitors once the initial right expires.[72] The result is that foundational patents usually cannot domi-

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66. The three controls on the problem of overclaiming are the requirements that patent claims be nonobvious and enabled and that the patentee provide a written description of the invention sufficient to demonstrate that it was fully conceived. *See* Cahoy, *supra* note 39, at 614-15.

67. This is allegedly the strategy employed by the famed Jerome Lemelson, who induced some of the country's largest companies to settle cases related to his questionable bar code patents rather than pursue cases in court. *See* Susan Hansen, *Breaking the (Bar) Code*, IP L. & BUS., Mar. 2004.

68. *See* Lemley, *Patenting Nanotechnology*, *supra* note 59, at 610-11 (describing widespread licensing of foundational biotechnology patents). *But see* Kumar & Rai, *supra* note 55, at 1754 (suggesting that the historical pattern of broad licensing in biotechnology may not occur in current technological contexts).

69. Sean T. Carnathan, *Patent Priority Disputes—A Proposed Re-Definition of "First-to-Invent,"* 49 ALA. L. REV. 755, 768-70 (1998) (explaining the requirement that a prospective patentee move forward with patenting diligently). The early disclosure incentive is even greater in countries that have a first-to-file system (which is most of the world). *Id.* at 757 ("In fact, every nation in the world except the United States and the Philippines follows a first-to-file system."). The patent rules also encourage a complete early disclosure, lest the doctrine of "prosecution history estoppel" narrow claims that were drafted too broadly or ambiguously. *See* R. Polk Wagner, *Reconsidering Estoppel: Patent Administration and the Failure of* Festo, 151 U. PA. L. REV. 159, 216-21 (2002).

70. Lemley, *Patenting Nanotechnology*, *supra* note 59, at 610-11 ("[A] number of early Federal Circuit decisions gave biotechnology patents a narrow scope, making it impossible to patent a broad genus based even on pioneering work and leaving the development of that genus open to others.").

71. 35 U.S.C. § 154(a)(2) (2000). The doctrine of prosecution laches may even serve as a barrier to delayed patenting within the twenty-year time period. *See* Symbol Techs., Inc. v. Lemelson Med., Educ. & Research Found., 422 F.3d 1378, 1385 (Fed. Cir. 2005), *amended in part on reh'g*, 429 F.3d 1051 (Fed. Cir. 2005).

72. Some refer to the process of extending patent rights through subsequent filings as "evergreening." *See, e.g.*, Rebecca S. Eisenberg, *The Role of the FDA in Innovation Policy*,

nate a technology for very long. In industries with long research and development lead times, they may expire just as a technology matures, or even before.

Finally, to the extent that fundamental technology patents result from federal grants, the government possesses the ability to compel licensing on reasonable terms. Under the Bayh-Dole Act's so-called "march-in" rights provision, the granting agency can compel the patent owner to license the invention if it is necessary, inter alia, to "achieve practical application of the subject invention" or "meet requirements for public use."[73] To date, such provisions have not been used,[74] but they remain viable and may serve as bargaining chips for policymakers.

Because foundational patents in biofuel technology are likely to experience the above limitations in a manner similar to general biotechnology,[75] their impact could be blunted. Such patents could figure prominently in early start-up periods, but they may not present an appreciable barrier to commercialization as the technology matures.[76] Instead of breadth, the larger patent menace may be the infamous thicket.

2. *Growing Thickets Through Diverse Ownership*

The world of applied science is filled with examples of "hot" technologies that suddenly capture the attention of academia and industry.[77] The shared interest among several parties in a particular inno-

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13 MICH. TELECOMM. & TECH. L. REV. 345, 348-49 (2007). However, subsequent patents do not, in and of themselves, restrict the use of inventions in prior patents. Unless some sort of regulatory structure (such as FDA approval) extends the power of subsequent patents, evergreening is rarely a major obstacle to innovation.

73. 35 U.S.C. § 203(a) (2000).

74. *See* Mark A. Lemley, *Are Universities Patent Trolls?*, 18 FORDHAM INTELL. PROP. MEDIA & ENT. L.J. 611, 628 (2008) [hereinafter Lemley, *Patent Trolls*].

75. See *supra* notes 27-37 for a description of biofuel technology, particularly second-generation research, which is essentially biotechnology based. Scholars have suggested that biotechnology did not suffer greatly from foundational patent coverage in part because the inventors were primarily located at universities, which "had strong norms against patenting, particularly in medical inventions." Lemley, *Patenting Nanotechnology*, *supra* note 59, at 609-10. Thus, the lack of intellectual property holdup was a result of unusual conditions that will not repeat themselves, particularly in view of the greater emphasis on patenting by universities. *See* Lemley, *Patent Trolls*, *supra* note 74, at 614-19 (discussing the rise in university patenting and the increased likelihood that they will engage in technology holdups).

76. *See* Duffy, *supra* note 55, at 464-75 (suggesting that early, broad patents channel competition that pushes back the filing dates, resulting in early dedication to the public, and presenting a model to demonstrate the concept).

77. For an economic explanation of this behavior, see James H. Cardon & Dan Sasaki, *Preemptive Search and R&D Clustering*, 29 RAND J. ECON 324 (1998). Historical examples in agricultural biotechnology include the race for genetically controlled herbicide resistance. *See* CHARLES, *supra* note 46, at 60-73; *see also* Samson Vermont, *Independent Invention as a Defense to Patent Infringement*, 105 MICH. L. REV. 475, 478-79 (2006); Malcolm

vation results in multiple research and development programs. Patents will typically result from such programs, even if the immediate practical applications are unclear. The property space can quickly become populated by a diverse collection of rights.[78] These rights may overlap or cover different aspects of the same product or service. This is true even when there are patents that claim a commercial embodiment of a product (a genetically modified seed, for example), as the embodiment may still be subject to patents on enabling technology or some other inherent aspect (a fundamental plant cloning technology or a particular herbicide regimen necessary to produce the product, for example). Overlapping rights may form what has become widely known as a patent thicket, a state in which it is impossible to find a clear path to commercialization without intruding on another's (or several others') patent rights.[79] Before a product or service can be marketed, all owners must assent, as any one owner has the power to hold up (or at least impose significant costs on) the technology.[80]

Theoretically, if all property owners could be identified, bargaining would always proceed to a rational end and the technology would be available at some price.[81] However, it has been suggested that behavioral barriers to bargaining remain when one party perceives an outsized opportunity to hold up another's valuable use. For example, Lemley and Shapiro assert that complementary patent owners will tend to demand excessive royalty rates that will make an invention

Gladwell, *In the Air*, NEW YORKER, May 12, 2008, at 50 (discussing the phenomenon of simultaneous invention when the pursuits of research programs are not necessarily public).

78. The rush to control a technology field of high interest through intellectual property is termed a patent race by economists. *See* LANDES & POSNER, *supra* note 40, at 300-01 (describing patent races); Michael Abramowicz, *Perfecting Patent Prizes*, 56 VAND. L. REV. 115, 183-90 (2003) (describing the phenomenon and noting the three primary problems with races).

79. Carl Shapiro, *Navigating the Patent Thicket: Cross Licenses, Patent Pools, and Standard Setting*, *in* 1 INNOVATION POLICY AND THE ECONOMY 119, 124-26 (Adam B. Jaffe et al. eds., 2001) (describing as a basis of patent thicket, the "holdup" problem "where hundreds if not thousands of patents . . . can potentially read on [the same] product"). A primary reason for the overlap is that patent rights include no use rights, but only the right to exclude others; thus, ownership of a patent conveys no freedom to operate. *See* Christopher M. Holman, *The Impact of Human Gene Patents on Innovation and Access: A Survey of Human Gene Patent Litigation*, 76 UMKC L. REV. 295, 302 (2007).

80. Lemley, *Patent Trolls*, *supra* note 74, at 613-14 (discussing the rise of patent holdups and, by extension, patent "trolls"). After the Supreme Court's *eBay* decision, it is less likely that the owner of a patent on a minor aspect of an invention will be granted injunctive rights. *See* eBay, Inc. v. MercExchange, LLC, 547 U.S. 388 (2006).

81. *See* F. Scott Kieff, *On Coordinating Transactions in Intellectual Property: A Response to Smith's* Delineating Entitlements in Information, 117 YALE L.J. POCKET PART 101, 108 (2007) (disputing the general notion that the number of patents in and of itself creates a hold-out problem and noting that "[p]atentees have a strong incentive to encourage use, not to block it").

unmarketable.[82] Heller points to research suggesting that there is an embedded tendency for such individualistic behavior.[83] But a review of the most commonly discussed examples indicates that this behavior is tied to a situation in which technology is already in production and cannot be abandoned; the manufacturer is over a proverbial barrel. On the other hand, if the manufacturer has yet to invest in substantial development efforts and can simply walk away from the project, the holdout power is dramatically reduced.[84] Thus, it makes sense to distinguish between ex ante patent negotiation, which occurs prior to development, and ex post negotiation, which occurs after development, in presuming persistent holdout behavior. The ex ante negotiation context is the correct one for biofuels and should stimulate rational bargaining.

Thus, the most troublesome quality of a thicket in nascent fields is the risk that one may not be able to conclusively determine all of the patents that read on a product or service. Relevant patents can pop up and catch even sophisticated manufacturers by surprise. Although it is possible to search the U.S. Patent and Trademark Office's database for inventions that appear facially similar, one might miss relevant patents due to subtle differences in language or an overly narrow conception of what constitutes an inventive aspect.[85] In addition, relevant patents may come to issuance subsequent to a comprehensive search (though the surprise is somewhat reduced by the ability to search published applications).[86]

Patent thickets have been theorized to act as a major obstacle to technology development in some fields. A single product may need to traverse so many overlapping rights that it requires hundreds, if not thousands, of licenses for production.[87] The inevitability of failing to

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82. Mark A. Lemley & Carl Shapiro, *Patent Holdup and Royalty Stacking*, 85 TEX. L. REV. 1991, 2003-04, 2010-11 (2007).

83. *See* HELLER, *supra* note 53, at 44 (citing the research of Sven Vanneste et al., *From "Tragedy" to "Disaster": Welfare Effects of Commons and Anticommons Dilemmas*, 26 INT'L REV. L. & ECON. 104 (2006), and Steven Stewart & David J. Bjornstad, *An Experimental Investigation of Predictions and Symmetries in the Tragedies of the Commons and Anticommons* (Joint Inst. for Energy and Env't, Report No. JIEE 2002-07, 2002)).

84. Lemley and Shapiro agree that this option reduces the holdup problem, but they assert that the likelihood of royalty overcharges persists unless the patent is "nothing special" or so "ironclad" as to be unassailable in litigation. Lemley & Shapiro, *supra* note 82, at 2003-04. Of course, the existence of royalty overcharging in this context does not mean that the invention will be abandoned.

85. Stewart E. Sterk, *Property Rules, Liability Rules, and Uncertainty About Property Rights*, 106 MICH. L. REV. 1285, 1298-99 (2008) ("Because of the notorious difficulty in assessing the breadth and coverage of patent claims, patent searches can be difficult and expensive.").

86. 35 U.S.C. § 122(b) (2000) (requiring publication of most U.S. patents after eighteen months).

87. *See* FTC, TO PROMOTE INNOVATION, *supra* note 45, ch. 3, at 34-35 (2003); Lemley, *Patent Trolls*, *supra* note 74, at 613; Doug Lichtman & Mark A. Lemley, *Rethinking Patent Law's Presumption of Validity*, 60 STAN. L. REV. 45, 55 (2007).

license at least one right supposedly leads to the rise of so-called patent "trolls"—patent owners who hold up technology for a toll without contributing anything to the progress of the useful arts.[88] The additional licensing and transaction costs can lead to underutilization of resources under a theoretical construct known as the "tragedy of the anticommons."[89]

Significantly, thickets or anticommons do not appear to be equally problematic in all industries. For example, some suggest that computer and software-related technologies—which, not coincidentally, are the industrial segments currently pushing for patent reform[90]—have a much greater problem with thicket formation than pharmaceuticals and biotechnology.[91] Developing fields may suffer more deeply from this pitfall. Before wide commercialization, diverse groups of inventors seeking to take advantage of an uncertain future market may exist.[92] The lack of clear market leaders reduces the barriers to possible adoption of new technology and makes the research and development risk worthwhile.

Are thickets or the anticommons likely to be a problem for biofuels? It should be acknowledged at the outset that these are elusive phenomena, and no one has devised a generally accepted method of identifying them; any predictions are necessarily somewhat speculative. However, there is certainly the potential for thicket formation if one analogizes the similarity in biofuel industry structure to early stage biotechnology. And early empirical evidence supports the possibility of thicket formation. The ownership of relevant patents is quite diverse, at least with respect to other highly developed segments of agricultural biotechnology. For example, one can compare the biofuel patent environment to that for genetically modified, her-

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88. Lemley, *Patent Trolls*, *supra* note 74, at 629.

89. *See generally* Heller & Eisenberg, *supra* note 12. Some scholars distinguish between thickets and the anticommons, while acknowledging that they are closely related. *See*, *e.g.*, Dan L. Burk & Mark A. Lemley, *Policy Levers in Patent Law*, 89 VA. L. REV. 1575, 1611-15 (2003). More recently, Mark A. Lemley suggested that the anticommons may not be as problematic as many believe because many companies simply "ignore patents" and innovate. Mark A. Lemley, *Ignoring Patents*, 2008 MICH. ST. L. REV. 19, 21-22 (2008).

90. *See* Clarisa Long, *Our Uniform Patent System*, FED. LAW., Feb. 2008, at 44, 45.

91. *Patent Reform Legislation – Public Comments on Substitute HR 2795 and the Role of the Antitrust Modernization Commission Before the Antitrust Modernization Comm.* (2005) (testimony of Mark A. Lemley), *available at* http://govinfo.library.unt.edu/amc/commission_hearings/pdf/Statement_Lemley.pdf ("[P]harmaceutical patents are more likely to cover a whole drug, rather than one of 5,000 different components of a semiconductor chip. So patent owners in the pharmaceutical industries don't have to worry about and [sic] endless stream of patent owners asserting rights in their drugs."). In his recent book, Heller makes the interesting assertion that pharmaceutical companies actually are troubled by the anticommons, but they essentially will not admit it because they are more concerned about the effect that weaker patents would have on challenges from generic pharmaceutical competitors. *See* HELLER, *supra* note 53, at 77.

92. *See* Lemley, *Patent Trolls*, *supra* note 74, at 614-19.

bicide-resistant plants (Table 1). The latter is a useful comparison group because the classification is specifically directed to a technology that could be considered the epitome of agricultural biotechnology in the 1980s and 1990s.

TABLE 1: COMPARISON OF PATENT OWNERSHIP IN THREE SEGMENTS OF AGRICULTURAL BIOTECHNOLOGY

	Corn GM Plants[93]	Non-Corn GM Plants[94]	Biofuel Technologies[95]
Number of Patents	525	1013	239
Number of Discrete Patent Owners[96]	37	118	77
Percent Ownership by Top 3 Firms	85.0%	69.6%	33.5%

Not only is the number of owners proportionally different in each segment, but the percentage of ownership is also dramatically lower

93. Numbers derived from the USPTO patents database for 1988 through 2008. USPTO Patent Full-Text and Image Database, http://patft.uspto.gov/netahtml/PTO/search-adv.htm (last visited June 1, 2009). Using classification 800, sub-classification 300.1 as a Boolean 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), relevant patents were identified. The authors chose this database, as well as the one noted in *infra* note 94, because its contents—patents directed to plants that have been genetically modified for herbicide resistance—are very specific to agricultural biotechnology and are unlikely to be contaminated with patents related to other industries. However, it is important to note that the consolidation of patent ownership in corn and noncorn GM plant inventions may be the result of overall industry trends rather than a past thicket/anticommons problem in this particular class.

94. Patents identified using classification 800, sub-classification 300 as a Boolean search term (Patents directed to Multicellular Living Organisms and Unmodified Parts Thereof and Related Processes: Herbicide resistant plant which is transgenic or mutant).

95. Patents identified using the search described in *supra* note 50.

96. Ownership determined by utilizing the assignment information on the face of the patent and modifying where dictated by using the USPTO's assignment records (http://assignments.uspto.gov/assignments/?db=pat) and public information regarding corporate consolidation. Patent ownership was consolidated as follows:

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:	Cargil, Agrigentics, Mycogen, Illinois Foundation.
Limagrain:	Soygenetics, Harris Moran.
BASF:	American Cyanamid.
Danisco:	Genencor, Xyrofin.
Verenium:	Diversa, Celunol.

in biofuel technology.[97] In the latter, no small group of firms is dominant.[98]

One might reasonably believe that, without additional influences, the biofuel patent landscape will grow dense and populated by trolls. Significantly, innovation may be underincentivized due to the costs in traversing the dense patent space. However, there are private forces that may have a great ability to reshape ownership trends and realign innovation. Whether they are beneficial to public innovation goals depends on the manner in which they are carried out.

III. THE PARADIGM OF PRIVATE ORDERING

Private ordering is the concept of self-regulation and realignment.[99] The term often refers to interactions in the absence of law.[100] However, a modern application is the private allocation of rights and duties against the background of public enforcement, with private contracting being a primary example of this form of mixed ordering.[101] This Article applies the mixed ordering definition and contrasts it with government regulation and reallocation of assets.[102]

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97. Note that, as a general rule, the percentage owned by the top three groups would be expected to be higher in the early stages of development, as only a few individuals or firms invest in invention. Thus, the contrast between biofuel and genetically modified plants is especially striking.

98. There is also evidence of a difference between biofuel technology and agricultural biotechnology in general. If one compares the biofuel ownership concentration to an extremely detailed U.S. Department of Agriculture Economic Research Service (USDA-ERS) calculation of agricultural biotechnology ownership patterns, one can see that the latter is clearly more concentrated. *See* USDA-ERS, Agricultural Biotechnology Intellectual Property: Overview Chart 4, http://www.ers.usda.gov/Data/AgBiotechIP/Gallery/Graphic4.htm (last visited June 1, 2009) [hereinafter USDA-ERS Patent Consolidation] (demonstrating a concentration of nearly forty percent for the top ten firms).

99. Steven L. Schwarcz, *Private Ordering*, 97 NW. U. L. REV. 319, 324-29 (2002) (noting that private ordering can be viewed on a spectrum with different levels of government participation).

100. *See, e.g.*, Barak D. Richman, *Firms, Courts, and Reputation Mechanisms: Towards a Positive Theory of Private Ordering*, 104 COLUM. L. REV. 2328, 2338 (2004) (stating that the literature of private ordering principally examines merchant communities that enforce agreements without state-sponsored courts).

101. *See* Jean Braucher, *New Frontiers in Private Ordering—An Introduction*, 49 ARIZ. L. REV. 577, 577-78 (2007) ("Contract law itself is a mixture of the public and the private, a means by which the state supports private ordering with remedies for breach of some promises."); *see also* F. Scott Kieff & Troy A. Paredes, *Engineering a Deal: Toward a Private Ordering Solution to the Anticommons Problem*, 48 B.C. L. REV. 111, 115 n.15 (2007) (stating, in the context of intellectual property transactions, that "we use 'private ordering' to refer to circumstances where parties, given extant legal and regulatory regimes, order the substance of their affairs and transactions as they see fit and resort to the judicial system for enforcement").

102. Although the ordering is private in the sense that firms continue to own the rights and decide when to deal, it is certainly possible for government to play a facilitating role. It can create incentives for ordering, for example, by rewarding efficiency and progress in technology development as endpoints, *see, e.g.*, Energy Independence and Security Act of 2007 (EISA), Pub. L. No. 110-140, § 207, 121 Stat. 1492, 1531 (grants for production of ad-

In this light, private ordering is a common aspect of the business environment.

The notion that private industry is inclined to collaborate to resolve patent barriers is not surprising. There is an obvious advantage to coordinating with other market participants to identify and address intellectual property rights that might complicate the introduction of new technology, particularly if a major player does not own it. The difficult task is to do it in a way that does not risk antitrust exposure. Whenever competitors collaborate, there is a danger that they may be entering into an agreement in restraint of trade.[103] This risk is compounded when the agreement concerns a market exclusion device such as a patent.

Interestingly, it seems that some industries are more inclined toward order. In determining whether second-generation biofuels constitute such an industry, it is worth first considering the strong tradition of collaboration in the sector that is most analogous: agricultural biotechnology. The analysis is particularly significant because it is a field that is not plagued by patent trolls. From agricultural biotechnology's history, one can identify several mechanisms that firms have used over the years to address intellectual property barriers. In general, they have survived antitrust scrutiny and thus provide a roadmap for the future of the biofuel industry if it is to avoid the pitfalls of thickets and holdouts.

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vanced biofuels), and by articulating legal structures that will not be challenged, *see, e.g.*, U.S. DEP'T OF JUSTICE AND FED. TRADE COMM'N, ANTITRUST GUIDELINES FOR THE LICENSING OF INTELLECTUAL PROPERTY (1995) [hereinafter DOJ/FTC 1995 GUIDELINES], *available at* http://www.ftc.gov/bc/0558.pdf. Alternatively, government can discourage ordering by creating uncertainty in antitrust prosecution or failing to follow through on guiding technology policy. In addition, regulation can play a major part in encouraging ordering by conferring market power on certain technology and eliminating the value in others. For example, genetically modified crops have permitted the technology to gain an important hold on certain types of food, but the extent of adoption is limited by regulation. WORLD HEALTH ORG. (WHO), FOOD SAFETY DEP'T, MODERN FOOD BIOTECHNOLOGY, HUMAN HEALTH AND DEVELOPMENT: AN EVIDENCE-BASED STUDY 4-5 (2005) (describing the genetically modified food crops that have been approved for sale in some countries but not others). *But see* Kieff & Paredes, *supra* note 101, at 145-46 (noting that ill-timed regulation can have a destabilizing effect on private ordering). This is something significantly less than central economic control, but it is an incursion on the pure market. One might argue that government action is best reserved unless there is evidence of a market failure.

103. However, in its 2000 guidelines on the matter, the Federal Trade Commission (FTC) and Department of Justice (DOJ) went out of their way to make clear that "[s]uch collaborations often are not only benign but procompetitive," so it is important to understand the legal limits. FED. TRADE COMM'N AND U.S. DEP'T OF JUSTICE, ANTITRUST GUIDELINES FOR COLLABORATIONS AMONG COMPETITORS 1 (2000) [hereinafter FTC/DOJ 2000 GUIDELINES], *available at* http://www.ftc.gov/os/2000/04/ftcdojguidelines.pdf.

A. Agricultural Biotechnology as a Historical Analogy

A primary reason the history of agricultural biotechnology intellectual property provides such a good model for what will occur in biofuels is that the connection to the basic science is the same.[104] In addition, many of the same companies that were involved in the development of early agricultural biotechnology are seeking a role in biofuels.[105] It is a rich story of technological development that is both informative and intriguing.

The basic techniques in agricultural biotechnology were first developed in universities and government labs in the 1970s.[106] Interest quickly spread to existing agricultural giants like Monsanto that had been dependent on chemical herbicides and fertilizers for tweaking crop yields.[107] The large agricultural firms worked to integrate genetically manipulated crops into their product lineup to generate sales. This was done either through original research and development,[108] outright purchases of technologies or smaller companies, joint development arrangements, or technology licensing.[109] Eventually, genetic science began to dominate certain crop segments such as soybeans,[110] and farmers began to view it as necessary to enjoy substantial yields.

When agricultural biotechnology was in its infancy, only a few researchers and firms were involved in patenting their inventions.[111] As interest grew and it was perceived as an integral technology for the

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104. *See supra* notes 27-37 (describing the biotechnology-related science of biofuels).

105. *See* sources cited *supra* note 51. However, the research undertaken for this Article suggests the patent environment is strongly characterized by enzyme-related companies. *See supra* note 50 and accompanying figure (charting patents resulting from a search for patents related to cellulosic ethanol production).

106. *See* Margie Patlak, Beyond Discovery: Designer Seeds (2003), http://www.beyonddiscovery.org/content/view.txt.asp?a=167 (describing the development of basic agricultural genetic science and highlighting its university origins in the context of a National Academy of Sciences-produced series of foundational stories).

107. *See*, *e.g.*, CHARLES, *supra* note 46, at 1-23 (providing a detailed and conversational account of Monsanto's growing interest in biotechnology techniques for manipulating plants); *Biotechnology Research: Weighing the Options for a New Public-Private Balance*, AGRIC. OUTLOOK, Oct. 1999, at 22 ("[I]t is increasingly evident that a sizable share of what was once considered exotic basic science . . . is being conducted in the private sphere by large life science firms, such as Novartis, Monsanto, DuPont, and Celera, and by many smaller biotech companies."); James H. Moore, Transaction Costs, Trust and Property Rights as Determinants of Organizational, Industrial and Technological Change: A Case Study in the Life Sciences Sector (1998) (on file with authors).

108. *Biotechnology Research*, *supra* note 107, at 22.

109. JOHN L. KING, CONCENTRATION AND TECHNOLOGY IN AGRICULTURAL INPUT INDUSTRIES 9-11 (2001), *available at* http://www.ers.usda.gov/publications/aib763/aib763.pdf; Michael R. Ward, *Emerging Competition Policy Issues in Agricultural Biotechnology*, 44 AM. BEHAV. SCIENTIST 504, 515-20 (2000).

110. FERNANDEZ-CORNEJO & MCBRIDE, *supra* note 46, at 4 ("Herbicide-tolerant soybean[] . . . [u]se expanded to about 17 percent of the soybean acreage in 1997, to 56 percent in 1999, and to 68 percent in 2001.").

111. KING, *supra* note 109, at 6.

future of the agricultural industry, more entities filed for patent protection.[112] For a time, the patent landscape became quite diverse. But a wave of consolidation soon swept the industry. Large companies like Monsanto, DuPont, and Syngenta began buying smaller companies to create large portfolios of patented technologies.[113] It was well known that they sought power, in part, through the ownership of key intellectual property assets. Consolidation was an important means of obtaining more control. Other players with connections to the pharmaceutical field, such as Novartis and Aventis, were also involved at various stages.[114] Most of these efforts resulted in either spin-offs, such as Bayer Crop Sciences, or the agricultural biotechnology assets being sold to one of the top four firms.[115] Eventually, a few companies once again dominated the patent landscape.[116]

The upside to the wave of consolidation is that the industry is now relatively compartmentalized. There are certainly a number of patent lawsuits among the big companies,[117] but there is little evidence that small parties or patent trolls are creating holdups in biotechnology development in general.[118] The potential for patent thickets has been significantly reduced. Interestingly, there has not been a great deal of resistance to these arrangements by antitrust authori-

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112. *See* John H. Barton & Peter Berger, *Patenting Agriculture*, 17 ISSUES SCI. & TECH. 43, 44-45 (2001) (describing several historical and legal events that led to a surge in patents on agricultural biotechnology).

113. KING, *supra* note 109, at 9-11.

114. *Id.* at 11.

115. *Id.* at 7 fig.3.

116. The USDA's Economic Research Service has provided a dramatic illustration of the consolidation trend in agricultural biotechnology patents by graphing patent ownership with and without consolidation figured in. *See* USDA-ERS Patent Consolidation, *supra* note 98.

117. A search of Westlaw's LitAlert database finds that Monsanto, Syngenta, and Pioneer Hi-Bred have been involved in forty-seven patent cases filed since August 2005.

118. The biotechnology industry's primary lobbying organization, the Biotechnology Industry Organization (BIO), issued a report in 2008 on pending patent reform litigation in which it addressed the existence of trolls. ANN MILLS & PATTI TERESKERZ, BIOTECHNOLOGY INDUS. ORG., PROPOSED PATENT REFORM LEGISLATION: LIMITATIONS OF EMPIRICAL DATA USED TO INFORM THE PUBLIC POLICY DEBATE 20 (2008), *available at* http://bio.org/ip/domestic/UVA_Limitations_of_Empirical_Data.pdf. It found that there was essentially no empirical evidence of trolls in major studies that motivated patent reform. *Id.* The most interesting highlight was of a survey by Walsh et al. of biomedical researchers that asked about the reasons for project abandonment. *Id.* at 17-18. "Too many patents" was a concern cited by only three percent of respondents. *Id.* Notably, Michael Heller rejects Walsh's findings by asserting that scientists are not aware of the effects of the anticommons. *See* HELLER, *supra* note 53, at 66-67, 77. He seems to suggest, in the face of survey evidence that contradicts his theory, that no survey can effectively capture the anticommons due to a variety of inherent biases or incomplete information. *See* Damien Geradin et al., *The Complements Problem Within Standard Setting: Assessing the Evidence on Royalty Stacking*, 14 B.U. J. SCI. & TECH. L. 144, 159 (2008) ("[V]oluntary market-based solutions appear capable of handling most of the licensing issues arising from any [anticommons] problems.").

ties,[119] though as discussed below, the possibility of anticompetitive behavior looms.

Given the similarities in technology, one predicts that biofuels will follow the general model of agricultural biotechnology. But this is only the starting point for the analysis. There are differences that may play an important role in charting a slightly different future for biofuels. For example, biofuels are part of a national energy policy,[120] the core field of biotechnology has developed substantially since its infancy in the early 1980s, and smaller entities like universities are becoming much more savvy about owning intellectual property.[121] At the very least, these differences suggest that, although the future intellectual property environment of biofuels is greatly informed by analogies to agricultural biotechnology, it is worth more in-depth study to ascertain the true likelihood of consolidation. To predict consolidation, one must have an appreciation of the possible pathways as well as the facilitating factors.

B. Beneficial Ordering Mechanisms

There are a number of possible iterations for ordering the biofuel innovation environment. Such ordering may involve the buying and selling of intellectual property rights to create permanent changes in the landscape. Alternatively, it may be brought about by some kind of licensing structure. The best form depends entirely on the owner and the technology. In fact, a broad patent environment may actually contain aspects of several ordering mechanisms, and the composition may change over time.

It is important to understand that the mechanisms of private ordering described below are by no means new or unusual; in various forms, they have long been essential tools in the management of intellectual property.[122] What is different is a perspective on these transactions as a method of large-scale private reorganization of the

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119. In general, antitrust authorities have acquiesced to the agricultural biotechnology industry mergers and licensing arrangements with only the requirement that certain assets be divested. *See*, *e.g.*, Novartis AG, Docket No. C-3979 (Fed. Trade Comm'n Dec. 15, 2000), *available at* http://www.ftc.gov/os/2000/12/novartisd_o.pdf (approving, in a consent decree, the merger of crop sciences divisions that now exist as Syngenta).

120. *See* Energy Independence and Security Act of 2007 (EISA), Pub. L. No. 110-140, § 202, 121 Stat. 1492, 1521-22 (to be codified at 42 U.S.C. § 7545) (dictating an increasing percentage of biofuel in transportation fuel through 2022).

121. *See* Lemley, *Patent Trolls*, *supra* note 74, at 614-15.

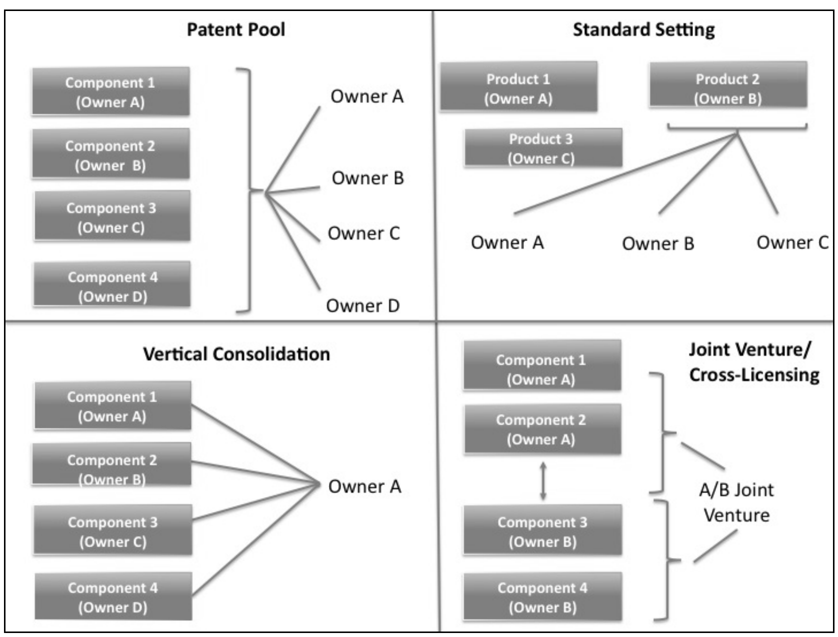
122. *See* SUZANNE SCOTCHMER, INNOVATION AND INCENTIVES 12-13 (2004) (describing the emergence of the business of invention in the 1800s predicated on the ability to sell patents, engage in joint ventures, and so on). Kieff and Paredes have considered the private ordering solution from the perspective of the conditions that must exist for an individual deal to take place rather than the conditions relevant for an entire industry. *See generally* Kieff & Paredes, *supra* note 101. Their analysis fits within the broader framework of this Article.

intellectual property environment. Through these various techniques, a field that was once crowded, impenetrable, and unproductive can become efficient.

1. Vertical Consolidation

In a highly fractioned patent environment, one company may struggle to gain access to sufficient patent rights to be able to market a product or deliver a service. Two or more firms may own different aspects of an embodiment, creating a barrier to a complete, "vertical" integration of rights.[123] One company may own a patent-enabling technology, another company may have the rights to the commercial embodiment, and a third company may control ancillary technology necessary to make the invention a commercial success.[124] If one firm has significant financial resources, the simplest solution to the problem is to purchase the necessary rights from the others and consolidate it into one company.

FIGURE 2: PRIVATE ORDERING MECHANISMS



A firm could undertake vertical consolidation by focusing on purchasing or licensing the patent rights and related assets in particular. It may be a successful strategy if the rights are the only important part of the embodiment held by others and if patent owners are willing to part with their exclusivity and possibly accompanying

123. *See* Ward, *supra* note 109, at 513-15.
124. *Id.*

"know-how."[125] However, it is probably more common and often more efficient to purchase the entire segment of a company that owns the rights. Along with patents, a purchaser may acquire important business management structure and perhaps ancillary intellectual property such as trademarks. A distribution chain may also be an important advantage in purchasing an established company.[126] Because it is not always easy to identify the necessary patent rights, complete vertical consolidation may take place over a period of years as the owners become clear.

Vertical consolidation will generally not present an antitrust problem because the owners of the rights are not in competition with each other (at least in the context of the invention in question).[127] None of the patent owners can market a product due to the holdout powers of the others. There is technically no competition to stifle. Therefore, the consolidation creates an overall competitive benefit because it allows something new on the market—technology that would not otherwise be available—that may compete with existing technology. For the same reasons, vertical integration in and of itself is generally good for overall technology development and can increase public welfare.

2. *Joint Ventures and Cross-Licensing*

When the patent environment is less dispersed, it might be possible to identify one or two technology owners who could combine their property and knowledge to make a complete product. Again, there may be synergies in corporate know-how in addition to complementary inventions. In such cases, it might be possible to bring the intellectual property owners together to create a joint venture.[128] This has the advantage of permitting each entity to retain ownership and a stake in the technology it developed. Beyond a certain number of intellectual property owners, however, this mechanism is probably not workable.

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125. *See* RICHARD RAZGAITIS, EARLY-STAGE TECHNOLOGIES: VALUATION AND PRICING 12 (1999) (discussing "outright sale agreements" for intellectual property and the fact that they are often accompanied by know-how, related machinery, and even relevant employees).

126. Professor Ward provides the example of Monsanto's acquisition of Dekalb, noting that it "married Monsanto's proprietary biotechnology intellectual property with Dekalb's highly complementary existing presence in seed markets." Ward, *supra* note 109, at 513.

127. *Id.* at 513-14 (noting the efficiencies of vertical consolidation); *see also* DOJ/FTC 1995 GUIDELINES, *supra* note 102, at 31 (discussing the FTC and DOJ analysis of intellectual property acquisition).

128. *See* Joseph Kattan, *Antitrust Analysis of Technology Joint Ventures: Allocative Efficiency and the Rewards of Innovation*, 61 ANTITRUST L.J. 937, 938-41 (1993) (describing the general purpose of most joint ventures).

Joint ventures are extremely common in agricultural biotechnology in the context of genetically modified seeds.[129] Often, a large agribusiness may purchase a percentage of a smaller agribusiness in order to combine existing technologies and work to create new products. A recent example is GreenLeaf Genetics, a joint venture between DuPont and Sygenta to out-license corn and soybean genetics and traits.[130] For the most part, joint ventures can avoid antitrust scrutiny so long as they do not excessively concentrate market power.[131] If it appears that the venture is actually a kind of market-cornering merger or, worse, an agreement not to compete on existing technologies, the joint venture can quickly lead to legal problems.[132]

Although a joint venture can be a significant way of facilitating the creation of otherwise stalled products by utilizing a transformed, hybrid corporate entity, many of the same advantages can be achieved by licensing. Achieving these advantages is particularly likely if there is a certain type of technology that is applicable to many products, but a deeper relationship with the technology owner is not advantageous.[133] Licensing has elements of standard-setting practice, but it is the product of two-party negotiation. In the context of agricultural biotechnology, one of the best examples is Roundup-Ready® genetically modified crops. This technology is owned by Monsanto but is incorporated into the seeds of some of its strongest competitors, including DuPont (Pioneer Hi-Bred)[134] and Syngenta.[135] It has become a very successful, widely-adopted genetically modified (GM) agricultural technology.[136]

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129. KING, *supra* note 109, at 9-10; Ward, *supra* note 109, at 518.

130. *Monsanto Gets Competitor in Syngenta Joint Venture*, ST. LOUIS BUS. J., Apr. 11, 2006, http://www.stlouis.bizjournals.com/stlouis/stories/2006/04/10/daily11.html.

131. *See* DOJ/FTC 1995 GUIDELINES, *supra* note 102, at 10-13 (discussing general principles of assessing intellectual property collaborations in innovation markets, which is where joint ventures generally take place); *see also* SCOTCHMER, *supra* note 122, at 172-74 (discussing analysis of antitrust effects of mergers and joint ventures from an innovation perspective).

132. *See* DOJ/FTC 1995 GUIDELINES, *supra* note 102, at 8-10 (providing an example where competitors form a joint venture to eliminate competition in licensing a process for manufacturing a drug, and noting that it could reduce competition).

133. However, the level of integration is closely related to whether the license is exclusive or nonexclusive. Exclusive licenses—wherein two companies are linked to the exclusion of other competitors—necessarily create more antitrust issues. *See* KING, *supra* note 109, at 10; Ward, *supra* note 109, at 519.

134. *Monsanto and DuPont Modify Roundup Ready License Agreement*, CHEMWEEK BUS. DAILY, Sept. 21, 2007 ("DuPont will pay Monsanto approximately $91 million/year over 2008-2015 for a total fee of $725 million, which DuPont says lowers its royalty payments by about 30% compared to its previous per-acre agreement.").

135. Press Release, Monsanto, Monsanto and Syngenta Reach Royalty-Bearing Licensing Agreement on Roundup Ready 2 Yield Soybean Technology (May 23, 2008), *available at* http://monsanto.mediaroom.com/index.php?s=43&item=604.

136. *See* Theodore M. Crosbie et al., *Plant Breeding: Past, Present, and Future*, *in* PLANT BREEDING: THE ARNEL R. HALLAUER INTERNATIONAL SYMPOSIUM 19-26 (Kendall R. Lamkey & Michael Lee eds., 2006) (detailing a discussion, largely authored by Monsan-

3. Patent Pooling

A patent-pooling structure is another step back in commitment and coordination from consolidation and joint ventures. It involves a licensing entity that administers several pieces of patent property in order to provide broad access to a number of companies.[137] Companies can usually access the protected information for licensed purposes in exchange for the payment of a set royalty.[138] The strategy of pooling is explicitly a response to patent holdups.[139] Once formed, patent pools induce wide participation as they present a level playing ground for all manufacturers (which is also a barrier to a patent pool's initial formation by companies desiring to exploit an intellectual property advantage).

Pooling arrangements are more common in high technology electronics; however, there are examples of agricultural pools. One such pool that has received a great deal of attention is the pool for the genetic material necessary to produce Golden Rice.[140] Another is the Public Intellectual Property Resource for Agriculture (PIPRA), a collaboration of universities and nonprofit institutions in several companies to make a variety of biotech innovations available.[141]

Patent pools are generally voluntary collaborations between knowing competitors.[142] However, it may be possible to compel parties to join the pool or risk losing revenue from a large segment of the industry.[143] They are strongly linked to standards for obvious rea-

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to employees, and describing the immense success of Roundup Ready products, especially soybeans).

137. Robert P. Merges, *Institutions for Intellectual Property Transactions: The Case of Patent Pools*, *in* EXPANDING THE BOUNDARIES OF INTELLECTUAL PROPERTY: INNOVATION POLICY FOR THE KNOWLEDGE SOCIETY 123, 129 (Rochelle Cooper Dreyfuss et al. eds., 2001); Shapiro, *supra* note 79, at 134.

138. Merges, *supra* note 137, at 123, 129.

139. U.S. DEP'T OF JUSTICE & FED. TRADE COMM'N, ANTITRUST ENFORCEMENT AND INTELLECTUAL PROPERTY RIGHTS: PROMOTING INNOVATION AND COMPETITION 64 (2007) [hereinafter FTC/DOJ 2007 REPORT] ("Patents pools also help to mitigate the 'hold up' and 'hold out' problems that can sometimes stymie industry efforts to make a product that conforms to an industry standard."); Shapiro, *supra* note 79, at 134.

140. David Serafino, *Survey of Patent Pools Demonstrates Variety of Purposes and Management Structures* 30-31 (Knowledge Ecology Int'l (KEI) Research Note 2007:6, 2007), *available at* www.keionline.org/misc-docs/ds-patentpools.pdf.

141. *Id.* at 32-33.

142. *See* Shapiro, *supra* note 79, at 134.

143. *See* Alan Cohen, *Patent Pools' Big Splash*, IP L. & BUS., Feb. 16, 2005, http://www.law.com/jsp/article.jsp?id=1108389913560 ("Pools can be structured to fix prices, stifle competition, discourage innovation, or divide markets. Yet increasingly, going it alone is a luxury companies just don't have."); *IGWG Briefing Paper on Patent Pools: Collective Management of Intellectual Property – The Use of Patent Pools to Expand Access to Essential Medical Technologies* (Knowledge Ecology Int'l (KEI) Research Note 2007:3, 2007), *available at* www.keionline.org/index.php?option=com_content&task=view&id=65 (asserting that a 1917 aircraft manufacturers patent pool was essentially compelled "against the backdrop of legislation threatening to compulsory license the patents").

sons.[144] Manufacturers may set out to identify relevant intellectual property and either purchase it for the pool or invite the owners to get involved. This coordinated effort may have the effect of cutting short the plans of a prospective patent troll.

As with consolidation and joint ventures, patent pools can avoid antitrust scrutiny under many circumstances.[145] The government may weigh in on the legality of the pool, although it is not required, as in the case of an outright merger of assets.[146] Most important is that pooled patents not consist of pure substitutes such that the pool necessarily represents a reduction in competition.[147] More generally, the pool must have procompetitive effects and not stand as a barrier to research and development.[148] When a patent pool is clearly ameliorating the effects of a patent thicket, the procompetitive case is relatively easy to make.[149]

4. *Standard Setting*

When firms perceive efficiency in adopting the same technological standard, a group effort—usually through an industry standard-setting organization (SSO)[150]—may develop to sort out the attributes.[151] Unlike patent pooling, this group effort can take place before intellectual property rights in an area have been perfected. In many respects, standard setting can be viewed as the antithesis of patent pooling in that the effort may be directed specifically to *avoid* existing and future intellectual property[152] (though a standard may incorporate a pool).[153] Often, technology parameters are chosen specifically because they are not subject to patent rights.[154] In this manner, a standard can transform the intellectual property environment

144. Merges, *supra* note 137, at 151 ("Even where there is no formal requirement along these lines, past practice exerts a powerful influence: having seen standards coalesce into pools, consumer electronics companies may simply expect this as the natural progression.").

145. *See, e.g.*, Shapiro, *supra* note 79, at 134-35 (discussing the Department of Justice's pronouncements on two permitted patent pools for DVD and MPEG technology).

146. *See* Clayton Act § 7A, 15 U.S.C. § 18 (2000) (providing the Hart-Scott-Rodino requirement for the filing of a notification of an intent to merge with the FTC and DOJ).

147. FTC/DOJ 2007 REPORT, *supra* note 139, at 74-77.

148. *Id.* at 67.

149. *See generally* Gavin Clarkson & David DeKorte, *The Problem of Patent Thickets in Convergent Technologies*, 1093 ANNALS N.Y. ACAD. SCI. 180 (2006) (arguing that the presence of a thicket weighs heavily in favor of permitting a particular patent pool).

150. FTC/DOJ 2007 REPORT, *supra* note 139, at 33-34.

151. *Id.* at 33.

152. *See* Lemley, *Ten Things*, *supra* note 60, at 154-55 ("[I]f a patent owner shows up in the standard-setting process after the irreversible investment is made, the investments have been made not just by one manufacturer but by everyone in the industry.").

153. Merges, *supra* note 137, at 151.

154. FTC/DOJ 2007 REPORT, *supra* note 139, at 41. However, it is often difficult to avoid patent rights, as they may not be evident when the standard is being set. Lemley, *Ten Things*, *supra* note 60, at 154.

by conferring or eliminating the market value that is the source of the asset's power.

In the agricultural biotechnology field, one finds standards primarily in safety and field-of-use guidelines. Prominent examples exist in the context of the push for organic farming and labeling for genetically modified crops. A regulatory structure for the former was imposed in 2002 under the National Organic Program, administered by the USDA.[155] However, the latter is subject to industry determinations of when labeling is appropriate.

It is possible to engage in de facto standard setting through the effects of network economics. A particular product may become viable only if it is integrated into a larger infrastructure, and the integration of one product may preclude the introduction of another.[156] This is a well-established issue in the context of biofuels. Some fuel sources would require significant changes in traditional aspects of refueling infrastructure[157] or automobile manufacturing[158] to receive widespread adoption. Changes to support such fuels may prejudice the adoption of others that might require an alternative design in vehicles or services. The voluntary industry adoption of one design over another has essentially the same effect as an agreed upon standard.

C. Conditions for Effective Private Ordering

Given the existence of so many useful and legal methods of private ordering, why is it that some industries seem to be unable to organize in this manner? For example, it is well known that computer-related industries consider the threat from patent "trolls" and other forms of unproductive litigation to be so severe that they actually desire weaker patent rights.[159] Clearly, private ordering has not occurred to the extent desired[160] (though there have been some large scale attempts),[161] and there is the belief that some technological ad-

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155. 7 C.F.R. § 205.100 (2008).

156. Lemley & McGowan, *supra* note 60, at 523.

157. *See generally* GOV'T ACCOUNTABILITY OFF. (GAO), BIOFUELS: DOE LACKS A STRATEGIC APPROACH TO COORDINATE INCREASING PRODUCTION WITH INFRASTRUCTURE DEVELOPMENT AND VEHICLE NEEDS (2007).

158. *See supra* notes 18-20 and accompanying text.

159. Gerard N. Magliocca, *Blackberries and Barnyards: Patent Trolls and the Perils of Innovation*, 82 NOTRE DAME L. REV. 1809, 1829-32 (2007) (suggesting conditions, which are more common in computer-related industries, that permit patent trolls to wreak havoc).

160. WENDY H. SCHACHT, CONG. RESEARCH SERV., PATENT REFORM: ISSUES IN THE BIOMEDICAL AND SOFTWARE INDUSTRIES, Report No. RL33367, at 9-10 (2006), *available at* http://fas.org/sgp//crs/misc/RL33367.pdf ("In addition, ownership of these patents may well be fractured among hundreds or thousands of different individuals and firms.").

161. Amy Kapczynski, *The Access to Knowledge Mobilization and the New Politics of Intellectual Property*, 117 YALE L.J. 804, 831-32 (2008) (describing the distribution of free

vancement has been held up.[162] On the other hand, the pharmaceutical industry has generally been able to organize and consolidate in a manner that maximizes the benefits of intellectual property protection.[163] This is not to say that substantial litigation does not exist in consolidated industries, but rather that the participants generally believe that intellectual property rights do not create a barrier to innovation and are necessary research and development incentives.

It is possible that the likelihood of private ordering is an immutable characteristic of particular industries. Only if the industry structure and the nature of the technology in question are favorable can private ordering occur. Otherwise, it will be nearly impossible for private actors to rearrange ownership rights in such a manner as to produce an efficient system for innovation. A student of law and economics will see this as an issue of transaction costs,[164] and indeed it is to a great extent. In essence, barriers to negotiation prevent the efficient ordering of rights through licensing and sales. It is therefore useful to consider the specific conditions that promote ordering.

A basic knowledge of patent transactions, industry structure, and essential technology allows one to intuit private ordering conditions with relative ease. The primary factors are first and foremost tied to technology, but they also depend on general industry practices. Notably, these factors clearly distinguish those technologies in which patent thickets are believed to pose the greatest problem.

1. *Limited Number of Patents*

In order for consolidation of patent assets to be a reasonable option, a firm or consortium of firms must have the ability to get a grasp on which patents might impact a particular technological embodiment. It is common sense that one can assess the value and necessity of purchasing patent rights only if one has some idea of the patent universe. But in many circumstances, assessing a patent universe can actually be quite difficult. If related rights can come from

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software as a means of avoiding the problems of diffused property rights); Don Clark, *WiMAX Patent Pool Is Planned*, WALL ST. J., June 9, 2008, at B6.

162. SCHACHT, *supra* note 160, at 10 ("In industries where innovation is sequential and complementary, as with software and computers, some experts argue that strong patents interfere with the innovation process.").

163. *See* Robert E. Thomas, *Vanquishing Copyright Pirates and Patent Trolls: The Divergent Evolution of Copyright and Patent Laws*, 43 AM. BUS. L.J. 689, 693 (2006) ("Large biotechnology, medical, and pharmaceutical companies (biotech/pharma) do not face the same threat that their info-tech counterparts face. This lack of cohesiveness has likely delayed or prevented the passage of some of the proposed patent reforms.").

164. *See, e.g.*, Garadin et al., *supra* note 118, at 154 ("Industry participants have tended to view rights dispersion in the single digits as concentrated and thus not problematic, primarily because transaction costs typically do not prohibit bilateral negotiations when a limited number of firms are involved.").

a practically unlimited number of sources directed at a tremendous variety of different product attributes, then even a diligent researcher may find it impossible to discover all potential infringements.[165] Additionally, the danger increases every day with the issuance of new patents. Therefore, for private ordering to be a reasonable possibility, the number of patents per product must be limited.

The pharmaceutical industry is often cited as an example of a field in which the number of patents covering a product is limited.[166] Although the industry is far from a one-patent, one-product model, it is certainly not unusual for the number of patents that impact a particular good to be in the single digits.[167] If one wished to license or purchase the rights to a given drug, it would be relatively easy to figure out which patents are involved. Moreover, it is quite likely that one company would own most (if not all) such patents, making the transaction significantly easier. On the other hand, in the computer-related fields, the number of patents that can read on aspects of a product could be in the hundreds, or even thousands.[168] Even a single piece of software installed on a computing device could be covered by dozens of patents. This makes comprehensive licensing difficult. Even technology licensed through patent pools offers no guarantee that infringement will be conclusively avoided.[169]

Another consideration may be the number of patents that tend to populate the entire technology space. Patent environments can be said to have a "density" that is formed by the web of interconnected patents.[170] Where there is a great deal of invention related to several popular technologies, the space quickly becomes denser. The density may, in and of itself, make it more difficult to ascertain the existence of patent rights and lead to product development that blindly trespasses on the rights of others. For this reason, it is fair to suggest that less dense patent environments favor private ordering.

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165. *See* Sterk, *supra* note 85, at 1298-99.

166. *See* Thomas, *supra* note 163, at 730 ("Biotech/pharma's . . . business model is based on selling products to end users that embody one or a very limited number of patents . . . .").

167. For example, some posit that in the pharmaceutical industry, "generally, one patent covers one drug." Lemley, *Ten Things*, *supra* note 60, at 150. That is an exaggeration, but the number of patents is often in the single or low double digits. *See* Daniel R. Cahoy, *Patent Fences and Constitutional Fence Posts: Property Barriers to Pharmaceutical Importation*, 15 FORDHAM INTELL. PROP. MEDIA & ENT. L.J. 623, 632 n.26 (2005).

168. Lemley, *Ten Things*, *supra* note 60, at 151 ("In IT, however, one product regularly involves the combination of 50, 100, even 1000, or—as Intel lawyers themselves say with respect to their own core microprocessor—5000 different patent rights.").

169. *See, e.g.*, Olga Kharif, *The Currents in an RFID Pool*, BUS. WK., Aug. 10, 2005, http://www.businessweek.com/technology/content/aug2005/tc20050810_7703_tc024.htm (quoting an industry member who states that there is no guarantee that all essential patent holders will participate in the RFID pool).

170. Clarkson & DeKorte, *supra* note 149, at 180.

As suggested earlier, there are reasons to believe that second-generation biofuels will be more like pharmaceuticals than like computer-related technologies. The patent space does not appear to be huge,[171] and the nature of the technology—methods and materials for producing a single chemical compound for use as a fuel—would be less likely to read on multiple patents. One could predict that biofuels will meet the first criteria for private ordering.

2. Significant R&D Barriers to Entry

Another aspect that tends to make a patent environment more inclined toward order is the existence of significant research and development costs for relevant innovation. If a company must invest a great deal in basic materials, research expertise, or time to an invention, smaller players will tend to be kept at bay.[172] By virtue of the smaller field, it is easier for ordering companies to devise an efficient strategy. A smaller field also reduces the chances that new players will simply pop up to claim ownership over an aspect of a product or process that another company is commercializing.[173] It should be relatively easy to identify almost all of the potential entrants. Moreover, significant research and development barriers may mean that even large, well-funded companies will be reluctant to begin parallel programs rather than purchase or license those already in existence.

Each of the three major segments of biofuel research is likely to have a significant barrier to entry, but not necessarily for the same reasons. The design and production of both enzymes and ethanologens is, for the most part, a typical biotechnology research cost barrier. To some extent, enzymes and ethanologens may operate synergistically such that a company that has an expertise in one is likely to have a great advantage in the other.[174] For example, a particular

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171. *See supra* note 50 and accompanying text. The relatively broad search uncovered only about 200 patents since 1988.

172. *Cf.* Long, *supra* note 90, at 45 ("The cost of much innovation in software today is relatively low when compared with the cost required by other industries, which means that independent inventors do not need the resources of large firms to invent products or processes.").

173. *See* Mark A. Lemley, *Intellectual Property Rights and Standard-Setting Organizations*, 90 CAL. L. REV. 1889, 1952-53 (2002) (noting that patents in industries like pharmaceuticals, biotechnology, and chemistry are harder to obtain and less likely to result in holdups).

174. *See* Anthony Crooks, *From Grass to Gas: On the Road to Energy Independence, How Soon Will Cellulosic Ethanol Be a Factor?*, USDA RURAL DEV., Sep. 2006, http://www.rurdev.usda.gov/rbs/pub/sep06/grass.htm; Ron Kotrba, *Incubation Through Integration*, ETHANOL PRODUCER MAG., Mar. 2006, http://www.ethanolproducer.com/article-print.jsp?article_id=1881 (discussing Broin's attempt to integrate research that impacts various stages of the ethanol production process); Dep't of Energy (DOE), Biomass Program: Past Solicitations, http://www1.eere.energy.gov/biomass/printable_versions/past_solicitations.html (last visited June 1, 2009) (indicating that Verenium is developing both enzymes and ethanologens).

enzyme may produce a type of sugar that is optimally converted to fuel by a certain microorganism. Coordinating these efforts has obvious advantages.

Biofuel plant technology can share many of the R&D attributes of enzymes and ethanologens, at least in the context of genetic modifications. But an additional issue is the time it takes to grow plant varieties in test plots. Many companies ameliorate these concerns by testing in climates that allow at least three growing cycles per year.[175] Compared to the extremely short doubling times for bacterial populations,[176] this is still quite lengthy. The time ends up being a significant additional barrier to the cost of materials and research expertise, effectively putting some plant technologies out of reach for all but the most established firms.

3. Existence of Complementing/Synergistic Infrastructure and Technology

One of the main reasons a company might choose to purchase or license another's technology is the existence of synergies. This is particularly true when that technology may impact part of a product or service that depends on the continued use of existing technologies for success. A new product attribute tacked onto an existing distribution network is an example of such synergy. It has been demonstrated in the context of the pharmaceutical industry that this is one of the most important factors underlying mergers.[177] Of course, buyouts of unrelated technologies undoubtedly occur to accomplish goals such as gaining a foothold in an emerging market.[178] But the potential for synergy acts at least as an accelerant, making it an important factor in whether private ordering will occur.

As previously stated, biofuel technology is not developed to the extent that one can conclusively determine what aspects truly exhibit synergy. However, the potential certainly exists. One can presume that natural connections between enzymes and ethanologens as described above could be important. Technology synergies may be more likely to occur when firms in established areas such as ethanol production or fuel transport have the opportunity to combine with firms that are on the cutting edge of a new line of research, like cellulosic

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175. Conversation with Tom Richard, Assoc. Professor, Dep't of Agric. and Biological Eng'g, Pa. State Univ. (Jul. 8, 2008).

176. ARTHUR KOCH, BACTERIAL GROWTH AND FORM 35 (2001) ("[S]ome bacteria under favorable conditions can double every 15 min.").

177. Patricia M. Danzon et al., *Mergers and Acquisitions in the Pharmaceutical and Biotech Industries*, 28 MANAGERIAL & DECISION ECON. 307, 319 (2007) (noting that one company's excess capacity due to patent expiration or other product sales declines is highly correlated with mergers).

178. *See* Ward, *supra* note 109, at 517.

conversion. And in plant sciences, a company's technology for high yields through insect and herbicide resistance[179] would strongly complement another's technology for facilitating the conversion from cellulose to fuel. More to the point, synergistic alliances are already occurring. Verenium, one of the more prominent biofuel companies, is a merger between the enzyme company Diversa and cellulosic ethanol processing company Celunol.[180] This creates at least a reasonable presumption that there is a sufficient amount of synergy and complementing technology to support ordering of the firms' respective technologies.

4. Long-Term Market for Technology

A final important factor in facilitating ordering is the likelihood that licensed or purchased technology will remain useful long enough to justify the investment in consolidation. In fast-moving fields, where technologies may become obsolete in a matter of two or three years,[181] making the effort to survey the field and engineer complex mergers may not make much sense. However, if such consolidations are likely to lead to research collaborations that pay off for decades, the effort is clearly supported.

The length of the market is impacted by consumer preference, obviously, but it is also influenced by a number of other factors that are not as subject to whim. Lengthy product development times may make it less likely that truly game-changing technologies stand ready to overtake the market in a short time period.[182] To the extent that the marketing of a technology entails the use of a standard agreed upon by many industry players, it is unlikely to change from year to year.[183] In addition, the presence of switching costs may delay or forestall the emergence of alternative technologies.[184]

In this matter, there is no great question on biofuels. The very fact that major breakthroughs are not predicted to occur for years into

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179. For example, Monsanto's Roundup-Ready® herbicide resistance technology, *see supra* notes 134-36 and accompanying text, would provide significant advantages in the production of plants with other biofuel-related genetic modifications.

180. Martin LaMonica, *Biofuels Firms Diversa, Celunol Merge*, CNETNEWS.COM, Feb. 12, 2007, http://news.cnet.com/Biofuels-firms-Diversa,-Celunol-merge/2100-11746_3-6158486.html; Press Release, Verenium, Diversa and Celunol Complete Merger to Create Verenium Corporation, a Leader in the Emerging Biofuels Industry (June 20, 2007), *available at* http://www.biotech.ufl.org/news/Celunol_DiversaBecomeVerenium21Jun07.pdf.

181. Cahoy, *supra* note 39, at 612 n.98 (describing the diminished value in patents when short product life cycles characterize the market).

182. For example, consider the fact that pharmaceutical product development times may extend to a decade or more. Gerald Mossinghoff, *Overview of the Hatch-Waxman Act and Its Impact on the Drug Development Process*, 54 FOOD & DRUG L.J. 187, 192-93 (1999) (providing a "New Medicines Timeline" that depicts lengthy product development times).

183. Lemley, *Ten Things*, *supra* note 60, at 154-55.

184. *See supra* note 61 and accompanying text.

the future[185] suggests that this is a technology segment with very lengthy development times. Analogies to general agricultural biotechnology support this presumption. In addition, the cost of pilot plants, not to mention full-scale production facilities,[186] means that it is unlikely that new technologies will emerge as market competitors in a short period of time. It is a well-supported notion that whatever second-generation biofuel technologies emerge as dominant will not change substantially over the short run.

D. The Danger of Horizontal Consolidation

To this point, it has been useful to consider consolidation in a positive light. The ability to navigate conflicting intellectual property rights addresses the initial concern of innovation holdup. However, consolidation can have a negative side. If the concentration of rights leads to a state wherein competition is suppressed or eliminated, the pathway to innovation that was anticipated to be cleared could in fact be shunted off course.

The negative form of concentration is what one might call "horizontal" consolidation.[187] Under this model, one company purchases intellectual property that covers competing products (or even the company owning competing property). Rather than marketing both products, efficiency generally dictates that the company eliminates one. Note that this is a different situation than a purchase to create synergies; it involves an acquisition that is primarily directed at a market competitor. Theoretically, this kind of consolidation can be positive when there is a need to coalesce around a single technology or standard for some efficiency reason, which could even have a competition-enhancing function.[188] But that would appear to be the exception rather than the rule, and it is particularly rare when the field is still emerging. More commonly, horizontal consolidation eliminates competing products to provide a single firm with a greater potential to profit.

Obviously, horizontal consolidation raises antitrust issues in the same manner that horizontal mergers do.[189] Regulators may challenge such asset purchases under some circumstances.[190] However, if

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185. *See supra* notes 36-37 and accompanying text.

186. EIA, *Biofuels*, *supra* note 30 ("Capital costs for a first-of-a-kind cellulosic ethanol plant with a capacity of 50 million gallon[s] per year are estimated by one leading producer to be $375 million (2005 dollars) . . . , as compared with $67 million for a corn-based plant of similar size . . . .").

187. *See* Ward, *supra* note 109, at 512-13 (discussing antitrust issues in horizontal combinations).

188. *Id.* at 513.

189. *See* DOJ/FTC 1995 GUIDELINES, *supra* note 102, at 8-10.

190. *Id.* at 31.

the purchase does not result in a significant concentration of market power, it is unlikely to be challenged.[191] For example, if the firms involved control a relatively small percentage of the market and the consolidated property will not change the equation at the time of the acquisition, it will generally not violate antitrust laws.[192] Significantly, the future potential of the property is the reason that this analysis may fall short. The fact that a consolidation of patent rights does not result in an immediate increase in market power does not speak to the possible loss in future innovation. The elimination of a vigorous competitor may prevent the research, development, and commercialization that would otherwise have built a stronger technology. It may even result in the elimination of any commercialization, as the purchasing company may have an alternative, less advanced product line that can be developed at a lower cost.

In the context of biofuels, the horizontal consolidation issue is particularly ripe. With the unknown potential of second-generation enzyme, plant, or ethanologen technology, it is entirely possible that several different solutions will arise to the same problems. Robust competition and a reasonably fair public vetting is the optimal way of determining which technologies are truly the best. But if good alternatives are instead purchased and buried, innovation may be severely compromised.

IV. INTEGRATING PRIVATE ORDERING EFFECTS INTO ENERGY POLICY

If one assumes that the conditions for private intellectual property ordering exist in the second-generation biofuel technology arena (or in any nascent technology field, for that matter), it is reasonable to draft public policy in response. Ignoring the impacts of patent rights appears to be the current policy,[193] and it goes without saying that this is ill-advised considering the increasing influence of patents. On the other hand, blindly drafting technology policy from a general understanding of patents is no better given the great differences that can exist in patent environments between technology fields. In doing so, one would likely cause more harm than good. An assessment of the actual patent landscape for biofuels is essential. But to be truly useful and effective, it must model the changes likely to take place in the future. Facilitating private ordering with an eye toward eliminating market failures and permitting private industry to align rationally is the overarching goal. In addition, it is important to apply

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191. *Id.*

192. *See* FTC/DOJ 2000 GUIDELINES, *supra* note 103, at 26.

193. *See* STEVE SUPPAN, INST. FOR AGRIC. AND TRADE POLICY, PATENTS: TAKEN FOR GRANTED IN PLANS FOR GLOBAL BIOFUELS MARKET (2007), http://www.iatp.org/iatp/publications.cfm?refid=100449.

a forward-looking policy beyond the question of innovation to address the broader supposed benefits and harms of this particular energy alternative.

A. Avoiding Innovation Holdups Through Disclosure

To a great extent, the function of private ordering suggests a largely laissez-faire approach. A structure that provides the greatest support for innovation, while minimizing the problems of holdouts on the one hand and horizontal consolidation on the other, is the obvious goal. The best way to achieve this is not a heavy-handed, forced pooling policy or greater antitrust scrutiny. It is information.

As suggested above, when the conditions are appropriate for private ordering, rational companies should bargain to allocate and license rights effectively.[194] However, one barrier to efficient bargaining is the market failure that comes from an information asymmetry.[195] In this case, the fact that a patent applicant or owner knows that the claimed invention covers a particular biofuel technology, but the commercial entity does not, creates an obvious obstacle to efficient coordination. In fact, it is the classic holdout problem that gives rise to patent trolls. Significantly, this can occur even in the midst of a consolidated industry (though it should be far less common).

A goal of biofuel innovation policy should be to eliminate the last vestiges of holdouts by increasing the disclosure of information. This should ideally be an ex ante mechanism, which would allow impacted companies to fully assess the patent environment before pursuing an invention. Essentially, it would involve compelling prospective patentees to stand up and declare the relevance of their inventions to biofuel technology. Although it would be impossible to simply impose such a disclosure requirement on the private market, it might be possible to facilitate it through federal incentives. Alternative energy is one of the more subsidized industrial segments, and it has great power over the agricultural industry;[196] perhaps these subsidies—whether tax credits or research grants—could be used as a carrot to promote such desired behavior.

There is precedent for a federal program that compels intellectual property ownership disclosure in exchange for a benefit. In the pharmaceutical context, companies that submit a new drug application (NDA) must affirmatively disclose to the Food and Drug Admin-

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194. *See supra* note 81 and accompanying text.

195. ROBERT COOTER & THOMAS ULEN, LAW & ECONOMICS 47 (4th ed. 2004) ("[S]evere asymmetries can disrupt markets so much that a social optimum cannot be achieved by voluntary exchange.").

196. *See* Doug Cameron, *Agribusiness Group Forms to Protect Ethanol Subsidies*, WALL ST. J., July 25, 2008, at A3.

istration patents that cover the drug.[197] A list of the relevant patents for each drug is contained in a publication (now in electronic form) known colloquially as the "Orange Book."[198] A failure to disclose a patent does not result in unenforceability, but there are consequences. Namely, a NDA owner will lose the ability to delay a generic competitor's approval through the Hatch-Waxman scheme,[199] a right that is potentially worth millions of dollars per day.[200] While this is not entirely analogous to the kinds of incentives in place for biofuels, it is nonetheless a demonstration that a federal disclosure system is possible.

Alternatively, the rise of standard-setting organizations or patent pools in biofuels may provide the opportunity to encourage disclosure as a condition for access. Since the recent stir caused by the Rambus company's ability to surreptitiously own patents covering a standard it helped promote through an industry organization,[201] standard-setting organizations will likely be much more cautious in requiring intellectual property disclosure. This private model will serve the same purpose in many instances as a compelled government regulation.

B. Social Policy Beyond Innovation Policy

Biofuels will provide an opportunity for rural development so long as the primary benefits 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. However, with the control of biofuels realigning to large agribusinesses through the consolidation of intellectual property, there may be a shortfall in the expected benefits. The initial positive of increased agricultural commodity prices[202] may be outweighed by problems created by increasingly constrained (i.e., less competitive) markets and limitations in dispersing ethanol production. In

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197. 21 U.S.C. § 355(b)(1), (c)(2) (2000).

198. *See* FDA, Electronic Orange Book: Approved Drug Products with Therapeutic Equivalence Evaluations, http://www.accessdata.fda.gov/scripts/cder/ob/default.cfm (last visited June 1, 2009).

199. 21 U.S.C. § 355(c)(3).

200. *See* David Balto, *Pharmaceutical Patent Settlements: The Antitrust Risks*, 55 FOOD & DRUG L.J. 321, 332 (2000) (quoting 180-Day Generic Drug Exclusivity for Abbreviated New Drug Applications, 64 Fed. Reg. 42,873, 42,882-83 (1999)) (describing how delaying generic entry can "mean tens of millions of dollars in increased revenue for an innovator firm").

201. *See*, *e.g.*, Rambus Inc. v. FTC, 522 F.3d 456, 459 (D.C. Cir. 2008) (finding that the FTC failed to demonstrate that Rambus's behavior was anticompetitive).

202. For example, a report authored for the USDA describes the emergence of the biofuel economy as a rural development opportunity based on an increase in agricultural commodity prices. DANIEL G. DE LA TORRE UGARTE ET AL., THE ECONOMIC IMPACTS OF BIOENERGY CROP PRODUCTION ON U.S. AGRICULTURE 19-20 (2003), *available at* http://www.usda.gov/oce/reports/energy/AER816Bi.pdf.

the end, consolidation may actually result in a net negative for rural development. That fact must be acknowledged, and the entire development angle to biofuels must be rethought.

According to economic theory, markets need to be competitive to maximize efficiencies and to fairly distribute benefits and harms. However, in the agrifood system, it has long been the case that profit margins are so narrow that horizontal integration is necessary in order to justify investment in research and development. If companies such as Monsanto, DuPont, and Syngenta had not succeeded in consolidating the seed industry,[203] then the capacity to accumulate profit from the agricultural production process may have been constrained, and the investments in agricultural biotechnology research and development would have been lower. Although this necessary ordering has produced social benefits beyond innovation in the form of the expanded use of more benign herbicides and fewer pesticide applications, the formation of oligopolistic agricultural markets has had negative impacts as well.

It has been suggested that the flow of agricultural production benefits to small farmers is diminished by industry consolidation. William Heffernan, for example, argues that farmers have a diminished decisionmaking capacity in the increasingly concentrated field, meaning that fewer are needed every year.[204] Essentially, the traditional family farmer is being replaced by the large agribusiness, and the food system is becoming just like other segments of the economy.[205] Heffernan believes that intellectual property plays a role in this due to its tendency to reduce competition in the food system.[206] By extension, consolidation of intellectual property interests in biofuel may have the same effects as in general agriculture.

One of the best examples of how powerful intellectual property rights can impact the interests of farmers concerns Monsanto's patents on Roundup-Ready® seeds. Monsanto (and similarly situated companies) have a great interest in protecting the innovation embodied in each seed.[207] In the case of Roundup®, this is a genetic modification that makes the plant resistant to the herbicide,[208] permitting

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203. *See* KING, *supra* note 109, at 9-11.

204. William D. Heffernan, Biotechnology and Mature Capitalism 2-3 (June 1999), *available at* http://www.foodcircles.missouri.edu/biotech.pdf.

205. *Id.* at 8-9.

206. *Id.*

207. *See* William Boyd, *Wonderful Potencies? Deep Structure and the Problem of Monopoly in Agricultural Biotechnology*, *in* ENGINEERING TROUBLE: BIOTECHNOLOGY AND ITS DISCONTENTS 24, 28 (Rachel A. Schurman & Dennis Doyle Takahashi Kelso eds, 2003). *See generally* Juan Enriquez, *Technology, Gene Research, and National Competitiveness*, *in* GLOBALIZATION AND THE RURAL ENVIRONMENT 225 (Otto T. Solbrig et al. eds., 2001).

208. JACK RALPH KLOPPENBURG, JR., FIRST THE SEED: THE POLITICAL ECONOMY OF PLANT BIOTECHNOLOGY: 1942–2000, at 244 (2d ed. 2005).

more precise weed control. Protecting this technology is not easy, as every single seed is a copy machine that can duplicate the modification and allow a farmer to avoid purchasing more seed the next year. In order to protect its interests, Monsanto uses a "bag tag" (also known as a "seed wrap"[209]) license that prevents farmers from saving seed in subsequent years.[210] To date, Monsanto has been successful in enforcing its license against individual farmers.[211] In doing so, arguably, it has eliminated the tradition of seed saving and changed the relationship between farmers and seed companies.[212]

Similar to the agrifood system, the biomass that will serve as the raw material supply for the biofuel industry will likely be supplied by hundreds of thousands of agricultural and forestry landowners. At least some policymakers seem to assume that as a result of the emerging biofuel sector, some of the same landowners supplying the raw materials for the agrifood system will have increased demand for their raw material outputs.[213] That increased demand will lead to higher prices for the farm outputs.[214] However, this assumption ignores the fact that farm producers purchase inputs and sell commodities in oligopolistic markets. Because of the limited competition in agricultural commodity purchasing and processing, farmers have little bargaining power. Since farmers will be marketing their biomass in a similar marketplace as the current agricultural commodity system, it is unlikely that economic benefits accruing to farmers will continue.

Experts also contend that to maximize environmental and economic benefits, biofuel processing facilities should be geographically diffuse and locally owned.[215] Due to the bulkiness of the biomass

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209. The title is an obvious homage to the shrink-wrap licenses from the software field. *See* Daniel R. Cahoy, *Oasis or Mirage? Efficient Breach as a Relief to the Burden of Contractual Recapture of Patent and Copyright Limitations*, 17 HARV. J.L. & TECH. 135, 152 (2003) (describing the "shrink-wrap" terminology).

210. *See* Adam Liptak, *Saving Seeds Subjects Farmers to Suits over Patent*, N.Y. TIMES, Nov. 2, 2003, at A18.

211. *See*, *e.g.,* Monsanto Co. v. Scruggs, 459 F.3d 1328 (Fed. Cir. 2006); Monsanto Co. v. McFarling (McFarling II), 363 F.3d 1336, 1339 (Fed. Cir. 2004).

212. *See* Keith Aoki, *Weeds, Seeds & Deeds: Recent Skirmishes in the Seed Wars*, 11 CARDOZO J. INT'L & COMP. L. 247, 253-57, 259 (2003); Sabrina Safrin, *Chain Reaction: How Property Begets Property*, 82 NOTRE DAME L. REV. 1917, 1917-18 (2007).

213. *See* DE LA TORRE UGARTE ET AL., *supra* note 202, at 19-20.

214. *See*, *e.g.*, 25X'25, ACTION PLAN: CHARTING AMERICA'S ENERGY FUTURE 5-6 (2007), *available at* http://www.25x25.org/storage/25x25/documents/IP%20Documents/Action_Plan/actionplan_64pg_11-11-07.pdf (claiming that the biofuel economy component of the plan to supply twenty-five percent of the nation's energy needs by 2025 will increase farm income by $180 billion and create 4 to 5 million new jobs).

215. David Swenson & Liesl Eathington, *Determining the Regional Economic Values of Ethanol Production in Iowa Considering Different Levels of Local Investment* 25-28 (Bio-Economy Working Group, Iowa State University, 2006), http://www.valuechains.org/bewg/Documents/eth_full0706.pdf; *see also* Alissa L. Meyer, Farming Fuels: Searching for Rural Revitalization in an Agricultural Bioeconomy (2008) (doctoral dissertation on file

feedstocks, energy efficiencies would be lost during the transportation to distant processing facilities. Ideally, then, biomass would be processed into fuel closer to the areas where the biomass is harvested. Furthermore, the economic benefits in the form of job creation and profit distribution are enhanced when those diffuse production facilities are locally owned.[216]

Oligopoly in the biofuel sector would not necessarily prevent the development of diffuse processing facilities. The major biofuel companies could develop a franchising system for production similar to that of petroleum distribution outlets. However, such a franchising system is not equivalent to local ownership. Furthermore, the dominance of the biofuel markets would most likely serve as a barrier to small companies with otherwise promising approaches to producing biofuels. New entrepreneurial efforts would fail not necessarily because they are less efficient, but because they will be seeking to enter a market that is not competitive. Since it is unlikely that the biofuel processing facilities will be locally owned, the economic benefits will be limited.

Policymakers need to consider difficult tradeoffs to achieve both environmental and economic benefits from the biofuel economy. The current context of private ordering of biofuel intellectual property may enhance environmental benefits at the expense of economic benefits.

V. CONCLUSION

Although biofuel policy is currently undergoing great scrutiny, policymakers have devoted insufficient attention to the relevant intellectual property environment. Given the fact that the future of this important technology resides in cutting edge research and development advances, it is very reasonable to assume that patents will play an important role. An overview of the current patent ownership landscape suggests that it is diverse and fractioned. Following the theories of Heller, Eisenberg, and others, one might be concerned that an anticommons is in the works, jeopardizing the future viability of biofuels. However, using agricultural biotechnology as a guiding heuristic, it is predictable that such an anticommons will not occur. The pattern of consolidation that has characterized agricultural biotechnology since the 1990s seems poised to reoccur. In articulating the framework and conditions for consolidation, this Article demonstrates that an anticommons will likely be avoided by private ordering of intellectual property rights. An optimal intellectual property

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with authors) (summarizing arguments that biofuel processing facilities should be geographically dispersed).

216. Swenson & Eathington, *supra* note 215, at 25-28.

policy will take this into account and foster the private market while ameliorating market failures that may permit some patent thickets to germinate. In addition, the broader impacts of consolidation will need to be considered in order to ensure that the interests of stakeholders beyond industry are not unduly compromised. The consequences of ignoring the impacts of private ordering in energy innovation are great. The potential for years of misdirected energy investment creates a critical need for such enhanced analysis.