

ENTERPRISE AND BIODIVERSITY: DO MARKET FORCES YIELD DIVERSITY OF LIFE?

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From the early 1900s, American farmers were becoming well able to “read” maize and recognize which physical characteristics translated into varying yields, quality, insect and disease resistance, and even aesthetic value. By 1925, the University of Illinois Department of Agronomy compiled a list of distinct corn strains totaling 19 (7 white strains and 12 yellow strains) (Fitzgerald 1993). By 1990, a market for privately produced hybrid maize seed in the United States had developed in excess of \$2 billion a year (Abelson 1990). Along with this market, and other hybrid seed markets, came the establishment of legally enforceable private property rights in the form of trade secret laws and the patentability of privately bred and engineered strains.

The existence of this market has brought sharp criticism from some individuals and organizations concerned with the effect of the market on biodiversity. Dawkins, Thom, and Carr (1996) conclude:

The emphasis on finding and isolating plants with the most marketable traits leads to the decline of other plant species, as only those required to create new techno-varieties are cultivated. . . . In addition, the privatization of genetic resources that have been engineered and patented accelerates the trend toward monocultural cropping.

According to such a view, the private maize seed market is detrimental to biodiversity. In contrast, others highlight the benefits associated with the private maize seed market. Stephen Smith (1996), a research fellow at Pioneer Hi-Bred International Inc., one of the largest producers of hybrid maize seed worldwide, noted: “If U.S. maize agriculture was today still using [nonprivate] varieties, U.S. maize production

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would be down annually by about 40–52 percent from its current level.” According to this view, the market for hybrid maize seed has made the production of maize, a staple food source, more efficient and abundant, benefiting humans fundamentally through enhanced nourishment.

At the root there appears to be a conflict between the efficiency of the market and the preservation of biodiversity. The conflict is real, however, only if the market is at odds with biodiversity. Does the market destroy biodiversity? We contend that it does not. Rather the market often can, and indeed does, *provide* biodiversity—both deliberately and as an unintended consequence of market forces. In the specific case of hybrid maize seed, we show that biodiversity is provided unintentionally both at the industry level and at the level of the individual firm. We explain that maize seed firms behave according to economic theories of monopolistic competition and optimal diversification, furnishing biodiversity as a fortuitous byproduct of their pursuit of profit.

Biodiversity and the Market

Consider the question of whether biodiversity can be a good provided by the market. Roger Sedjo (1992: 199) observes: “It is well recognized that wild genetic resources—the genetic constitutions of plants and animals—have substantial social and economic value as repositories of genetic information.” The value of such genetic information can be realized within, but not exclusively within, the development of drugs and pharmaceuticals, the commercial markets for hybrid seed, the selective breeding of cattle, and the enjoyment many of us find intrinsic in the many shapes and forms of nature. But can these biological resources be preserved and provided under a system of private property rights that are exchanged via markets? Many individuals and organizations feel that the market mechanism of resource allocation is incompatible with, and a threat to, biodiversity. For instance, the Institute for Agriculture and Trade Policy (1996) has expressed deep concern that “the privatization of [biological] knowledge threatens biodiversity.” Even popular economic textbooks speak of “market failure” in the case of various environmental issues, including biodiversity, and proliferate the view that “if society wishes to improve the quality of the environment it is necessary for government to establish environmental standards” (Peterson 1991: 185–86). Two economists who have focused their attention on biodiversity have gone so far as to write: “Pollution, population, and the market—these are

the three principal pressures threatening biodiversity ” (Olson and Swaney 1992: 4).

Is the market system at odds with biodiversity? The market is the mechanism by which private property rights to utilize resources are exchanged between individuals, or groups of individuals, at prices that render the exchanges beneficial to the parties involved. A system of private property rights can be defined as the situation where “each thing is controlled by an individual who has the power to transfer that control to any other individual” (Friedman 1989: 4). Another way to think of private property rights is that they are “*rights to use resources*” (Alchian and Demsetz 1973: 17). Well-defined property rights include the right to use, the right to receive revenues from use, and the right to transfer.

Before one can explore the compatibility of the market system with biodiversity, one must ponder not only whether the property rights to biodiversity itself can be privately held, but also whether property rights to biological traits, knowledge, species, tissues, cells, and genes can be privately held. These issues affect the direct provision of biodiversity in the market, as well as the indirect provision of biodiversity as a natural byproduct of market interaction.

To begin with some basics, a dictionary definition for biodiversity is: “Biological diversity in an environment as indicated by numbers of different species of plants and animals” (Merriam-Webster 1993: 115). This is simplistic in that it does not reveal the vast amount of biodiversity recognized *within* a given species;¹ nevertheless the definition is useful in that it points out that biodiversity is found in different frameworks—the dictionary terms these frameworks “environment[s].” This is important because biodiversity is not solely interpreted in a global sense; biodiversity exists as well within smaller frameworks, such as a farmer’s fields, an individual’s backyard, genetic make-ups within one unique species, and the greenhouse of a flower shop.

Depending on the context, biodiversity need not necessarily be a good thing. Consider the horticulturist who diligently pulls weeds and sprays his or her prize-winning flower garden with pesticides, or the tropical fish hobbyist who regularly cleans the aquarium so that specific

¹In fact, the value of biological diversity within human cells and tissues, as potential for commercial applications in biotechnology increases, alone has been enough for property rights to be considered in court. For a discussion of one such legal case, see *John Moore v. Regents of the University of California*, where John Moore, a victim of cancer, was decided against when “the [California Supreme Court] once again held to its traditional position that individuals do not hold property rights in their own tissues and cells” (Greenberg and Kamin 1993: 1071).

fish are the only thriving life forms. In flower and vegetable gardens, aquariums, pet stores, hospitals, and even our own bodies (consider what we use penicillin for), increasing biodiversity can certainly foster disutility. Nevertheless, for convenience sake, biodiversity will be thought of as a good throughout the remaining discussion.

In many cases, biodiversity itself is indeed a good and falls under well-defined property rights. In situations characterized by low transaction costs, voluntary exchanges of individuals and groups of individuals assure that the good is provided to the mutual benefit of the concerned parties.

Consider now a specific case in which biodiversity is a good with well-defined property rights that are exchanged in a fluid market, namely game ranching:

Game ranching is a truly private enterprise. It is the private ownership of wildlife carried out on private property, typically for profit. In the U.S., the ownership of domestic wildlife is divided between state and federal governments. Most game ranchers raise “exotics,” that is, non-native animals not traditionally farmed or ranched. Those species can be privately owned under U.S. law [Sugg 1992: 10].

These game ranches are quite biodiverse in their livestock. Ike Sugg (1992: 10) also reports, for example, that the Exotic Wildlife Association, an international game ranching organization, estimated its ownership in 1992 at 200,000 head of approximately 125 species. Interestingly, Sugg (1992: 10) further notes that over 19,000 of those head belonged to species which are considered threatened or endangered in their natural environments; and some species, such as the Scimitar-horned oryx, owe their present existence to game ranchers. In the case of game ranching, profit motivates ranchers to cultivate a product—biodiversity of game—as an investment, the cost of which is less than hunters value the chance at exotic sport, pelts, and meat. The result: biodiversity is provided by the exchange of property rights from ranchers to hunters.²

Consider next the commonplace case of tropical fish collectors. Collectors gain utility from maintaining populations of tropical fish in aquariums and, as one would suspect, their demand is answered by other parties who are willing to supply the fish. Mbuna Coast

²Another facet, or extension, of the market provision of biodiversity in the “big game” context occurs when the supplier (or demander) is biodiversity conscious. Consider the case of the Rocky Mountain Elk Foundation of Alberta, Canada, which each year auctions two hunting permits only (one each for bighorn sheep and elk) to help pay for its purchases of wildlife habitat and its program of conservation management. Reuters (1998) reported that one well-heeled hunter had actually paid the Foundation the princely sum of \$405,000 for the right to shoot a single bighorn sheep sometime during the month of November.

Aquatics, located in Austin, Texas, was established in 1994 and has since specialized in providing tropical fish collectors with different types of African cichlids (rockfish), native to Africa's Great Rift Lakes. The company ships these fish to customers, the fish having been "selectively raised or carefully imported either from [their] hatchery or from other dedicated hobbyists" (Mbuna Coast Aquatics 1996). Once more, a profit-motivated supplier invests in the cultivation of a certain frame of biodiversity at a cost less than what it would cost those who demand that frame of biodiversity, and the result is mutually beneficial exchange on the market.

Situations in which individuals value biodiversity itself constitute but one way in which the market can provide biodiversity. Biodiversity can also be produced as a byproduct of the market.³ Consider the demand for tea. Many consumers have a favorite brand, or a narrow range of favorite teas. The consumer who enjoys Earl Grey may not care at all about the diversity of tea plants on the planet; the same would be true of the consumer who fancies only green tea. However, the Ten Ren Tea and Ginseng Company of New York, New York, provides teas to a wide range of these tea consumers. Owned and operated by fourth generation tea farmers, Ten Ren Tea and Ginseng Company (1996) explains that it grows and processes more than 30 varieties of tea from different leaves native to different regions of the world. Even though tea consumers need not care about a biodiverse supply of tea leaves for brewing, the market, catering to the numerous desires of individuals, provides such a biodiverse supply. Furthermore, Ten Ren Tea and Ginseng Company need not be concerned with tea leaf biodiversity in any moral or ethical sense, but need only have a commercial interest in tea leaf biodiversity for such biodiversity to be brought forth as an unintended consequence of market processes.

Also consider Select Breeders Service, Inc. (1996), a company specializing in stallion semen "cryopreservation." For horse breeders who are either looking to profit through the virility of their stallions, or looking to inseminate their mares with sperm from a stallion with

³It is interesting to note that the modern environmentalist movement—associated with the ideological left—more often than not is fervently opposed to the market as a solution to environmental concerns, including biodiversity. However, one of the most prevalent criticisms of the market system from the ideological left concerns advertising, which has been classified under two types: informative and persuasive. While few take issue with informative advertising, many claim that persuasive advertising is an effort to differentiate a firm's products from those of other firms, the effect being a decrease in the elasticity of demand facing the advertising firm. As the elasticity of demand decreases, firms active in persuasive advertising enjoy more monopoly power (Peterson 1991: 255–57). Following from this, the criticism becomes that the market allows for too large a range of similar products to be produced: *too much product diversity!*

desirable traits, Select Breeders Service will freeze stallion semen and ship it nationwide. The frozen product remains viable in cryogenic freeze for over eight years (a figure based on the longest term supported by the success of Select Breeders Service in achieving the pregnancies of mares). Once again, no horse breeder need care about biodiversity for its own sake. Stallion owners need only concern themselves with the profits attainable through the sale of their stallions' semen. Mare owners need only care about impregnating their horses with what will someday be a beautiful, fast horse. And once again, Select Breeders Service, Inc. need only be concerned with the profit to be gained with their cryogenic and transportation services, including a \$150 handling fee for shipment of the good. Still, the result is genetic (bio)diversity being shipped nationwide to be combined with other sources of genetic diversity. Because purchasing customers have diverse individual preferences of equine traits, biodiversity of horses obtains.

Our examples point to the fact that market provision of biodiversity occurs in two essentially different contexts: first, as a direct product, when biodiversity itself is sought by demanders and furnished directly by suppliers (such as with game ranching or tropical fish); and second, more subtly, as a naturally occurring byproduct, as when particular private goods are sought by idiosyncratic demanders and are furnished by suppliers who unintentionally provide biodiversity (such as with tea). In the latter context, the resultant biodiversity can be considered unintentional in multiple ways. First of all, it is the prospect of gains from trade that motivates the market behavior of suppliers and demanders, not especially or necessarily a concern for biodiversity. Also, when a profit-motivated, individual supplier furnishes a biodiverse product line it may merely be because that supplier happens to deal with a variety of demanders, none of whom individually need care about product (bio)diversity. In addition, even in situations in which specialized suppliers provide only a singular product to specific demanders, suppliers nonetheless individually contribute to an aggregate biodiversity that was no part of their intention. Like many other salubrious consequences of market forces, no one has to plan for biodiversity in these contexts, but it happens nonetheless.

As the market furnishes private goods to private demanders, biodiversity can arise spontaneously. Even more remarkable is that market-induced biodiversity can emerge in contexts in which biodiversity is itself a public good, meaning a good that has the characteristics of being nonrival (many can consume it jointly without interference) and nonexclusive (if it is provided to any one consumer, it is provided to many, perhaps all, consumers). By way of example, and in part

anticipating the results of our detailed study of the maize seed market presented in the next section, consider biodiversity of maize seed as being a public good: all of us simultaneously may consume the existence/preservation of multiple strains of maize seed (though, of course, not the seed itself); and if multiple strains exist in the world for any one of us, they exist for all of us. In the next section we amply document that the market does in fact provide a substantial variety of maize seed, thus demonstrating (among other things) that the market can provide biodiversity when biodiversity is itself a public good. Here again, as previously noted, the provision of biodiversity need be no one's intention or conscious plan. Biodiversity arises as a natural byproduct of commerce.⁴

Biodiversity in the Maize Seed Market

Having demonstrated two ways by which the market produces biodiversity—as both a direct product and a naturally occurring byproduct—we now turn to our focal market: the market for hybrid maize seed. Individual farmers desire specific and idiosyncratic attributes in the maize they purchase:

⁴We want to carefully delineate our findings here. Our chosen task has been to refute the claim that the market is at odds with biodiversity. We note examples, including a “public good” example, which support our case. We do not here attempt to answer the question of whether the market provides optimal amounts of biodiversity, however that might be defined. That question is quite loaded, perhaps requiring an analysis of biodiversity as it relates to the notions of future option value (see, for example, Simpson, Sedjo, and Reid 1996) and existence value (see, for example, Nelson 1997), and the controversial methodology of contingent valuation (see, for example, Portnoy 1994; Hanemann 1994; and Diamond and Hausmann 1994). We would quickly note, however, as a policy matter it is clearly by now insufficient merely to call attention to a level of market provision of biodiversity that falls short of a theoretically constructed norm of optimal provision as indicative of a need for public provision. For example, in the case of biodiversity seen as a public good, those who would advocate public provision must address the troublesome issue of how to determine the correct level of public provision of an untraded commodity (see, for example, Demsetz 1964). Also, account must be taken of issues related to compelling legitimate holdouts to pay for an unwanted “good” (see, for example, Garrett 1992 and Schmidt 1991). Moreover, as pointed out recently and tellingly by Stroup (1997: 1), whereas public provision of the public good is advocated as a way around the free-rider problem associated with those who will not pay for voluntary provision, public provision

usually involves large information requirements, complex decisions, performance monitoring, and the enforcement of contracts. Who, among taxpayers-voters, will constantly monitor the flow of information and set aside the time needed to help supervise the political and bureaucratic processes in which these decisions are made? Such oversight is needed to assure that the interests of the general public are served, rather than the special interests. . . . [Yet] each citizen has an incentive to act as a free rider on the diligence of others. . . . Control of public decisions is itself a public good, subject to the same free rider problem that plagues the private provision of public goods.

For example, in humid southeast United States a particular hazard is viral disease. In other areas the problem may be periodic droughts. In Minnesota the short length of the growing season requires a fast maturing variety. In other areas the best yields are obtained from slower maturing hybrids. In heavy clay soils there is root rot. Almost everywhere there is the European corn borer. High-yielding tall corn can be blown over during storms. Strength of stalks and roots is important. New pathogens appear. Mutant varieties of older ones arise [Abelson 1990: 837].

Note that no individual farmer need value biodiversity in maize for biodiversity to be produced via the market as a byproduct.⁵ Each farmer values a component or components of biodiversity (i.e., certain seed or seeds with qualities desirable according to the individual farmer's situation.) Seed companies, who breed or genetically engineer seeds with various qualities, recognize that farmers value seed at an amount greater than the cost to the firm in producing the seed. Property rights are transferred from the seed companies to individual farmers—enough to create a maize seed market of more than \$2 billion per annum (Abelson 1990: 837)—with benefit accruing to both parties. The result: biodiversity flourishes as a byproduct of the market system.

There were 72.1 million acres of maize harvested in the United States in 1992 (U.S. Bureau of the Census 1995). A study by Smith et al. (1992) of a random sample of 11,256 maize farmers from 38 states found that 124 distinct commercial hybrid strains were being planted on at most 0.1 percent of total acreage; furthermore, these same researchers found the greatest percentage of total acreage in

⁵For the purposes of this paper, biodiversity in the hybrid maize seed market will be defined as numbers of distinct strains offered by seed-producing firms. These strains are usually defined as distinct by the physical characteristics of the maize. This definition can and has been viewed as a weakness: "Private breeding will not contribute to genetic diversity because private breeders use popular public varieties as parents and need to perform only the minimum amount of cosmetic breeding to qualify a variety as new under PVPA [the Plant Variety Protection Act of 1970]" (Pray and Knudson 1994: 102). However, as has been mentioned above, a dictionary definition only defines biodiversity as the *number of species*, and that particular definition ignored *the genetic diversity within a species*. Now the concern of *the amount of genetic diversity within a species* has been raised. All that can be concluded is that there are varying and unresolved conflicts as to how biodiversity is defined. Still, unique private strains of maize seed are indeed genetically different to some degree. This is admitted by all participants in the debate. Following from this, if one can view the dictionary definition as one extreme and the view mentioned by Pray and Knudson (1994) as another extreme, then defining biodiversity by numbers of, to some extent, genetically and physically unique maize hybrid strains can be the method utilized by this paper with a relatively clear conscience.

1992 that was planted to a single hybrid was 4.7 percent.⁶ So without any of the parties involved in the maize seed market necessarily seeking biodiversity for its own sake, the market induces biodiversity as a byproduct of human commercial action and interaction.⁷

The market for maize seed also furnishes biodiversity at the firm level, owing to the incentives of individual suppliers emanating from the structure of the maize seed industry. An analysis of industry structure leads to the rejection of the purely competitive model in favor of a model of monopolistic competition. Combining the model of monopolistic competition with an analysis of portfolio diversification and managerial behavior theory reveals why an individual firm has incentives to furnish biodiversity.

Monopolistic Competition in the Maize Seed Industry

One of the major indicators of a perfectly competitive industry is that firms produce undifferentiated products (Gwartney and Stroup 1997: 211).⁸ This follows from the perfectly competitive assumption that firms can only compete as far as the price of the product is concerned. In a classic treatment of the issue, Edward H. Chamberlin (1933: 8) observes: "The utilities offered by all sellers to all buyers must be identical, otherwise sellers have a degree of control over their individual prices." However, an undifferentiated product is not observed in the hybrid maize industry. In fact, numerous different strains of maize are being offered by many firms.

As can be seen in the sample of firms in Table 1, the maize seed industry is definitely producing biodiversity. There are 338 varieties of maize offered. Some are offered for certain climates, and others for certain ground conditions, and still others for resilience against

⁶Dawkins, Thom, and Carr (1996) of the Institute of Agriculture and Trade Policy claim that "privatization of genetic resources that have been engineered and patented accelerates the trend toward monocultural cropping." However, the fact that the maximum acreage planted to a single hybrid was 4.7 percent out of 124 primary hybrids lends little support to this view.

⁷A parallel can be drawn to the growing interest in cultural diversity or "multiculturalism." Here, perhaps, specialization of labor provides incentives for various cultural adaptations, making multiculturalism a byproduct of the market.

⁸Gwartney and Stroup (1997: 211) generally use the modern terminology of "price-taker" firms rather than the traditional equivalent of "competitive" firms, though they explain that the terms are "merely alternative names for the same thing." Herein we elect the historically imbued terminology of "monopolistic competition" as opposed to the modern alternative of "competitive price searcher," even though it is less descriptively precise (Gwartney and Stroup 1997: 236), because it facilitates a uniform and useful application in what follows of some decades-old, classic references from the field of industrial organization.

TABLE 1
 MAIZE SEED COMPANIES AND THE NUMBER OF HYBRID
 VARIETIES OFFERED IN 1996

Company	Number of Hybrids
Pioneer Hi-Bred International, Inc.	151
Mycogen Corporation	61
Cargill, Incorporated	34
Asgrow Seed Company	31
Wyffels Hybrids, Inc.	15
Redwood City Seed Company	13
Shepherd Popcorn	13
Dekalb Genetics	12
Seeds of Change	8

NOTE: Seed offerings are available at the various Web sites of maize seed companies listed in the references at the end of this paper.

insects and/or disease. Some varieties are offered for ordinary human consumption, some for animal feed, others for food ingredients, and still others for popcorn.⁹

Having demonstrated that the industry is producing biodiversity, and recognizing that such behavior is not strictly compatible with the perfectly competitive (homogenous commodity) model, we must determine if a model can be described which explains the behavior of the maize seed industry. Over 60 years ago, Chamberlin (1933: 56) wrote of the product differentiation which is often found in industries:

Differentiation may be based upon certain characteristics of the product itself, such as exclusive patented features; trade-marks; trade names; peculiarities of the package or container, if any; or singularity in quality, design, color, or style. It may also exist with respect to the conditions surrounding its sale. In retail trade, to take only one instance, these conditions include such factors as the convenience of the seller's locations, the general tone or character of his establishment, his way of doing business, his reputation for fair dealing, courtesy, efficiency, and all the personal links which attach his customers either to himself or to those employed by him.

⁹For descriptions of different hybrid varieties and their characteristics see the company Web pages listed among our references. Also, for a description of the many common (and not so common) uses of maize, see The Kansas Corn Growers Association (1996). Such uses include, but are not limited to, food in and of itself, starch and sweeteners for other foods, alcohol to power cars and a variety of other engines, animal feed, and cooking oil from the extract of the kernel.

From Chamberlin's discussion of the nature of product differentiation, many features of the maize seed industry can be found. As far as the product itself, patents and trade-secret laws provide some exclusivity of product features to different firms in the industry. Patents are obtained through the U.S. Patent and Trademark Office and grant authors and investors exclusive right to manufacture or sell (or choose who will sell) their discoveries, inventions, or writings for 17 years from the issuance of a patent.¹⁰ Maize-related patents have been greatly facilitated by the passing of the Plant Variety Protection Act (PVPA) of 1970, which allowed for plant varieties to be protected as intellectual property (Pray and Knudson 1994). Though a relatively recent development, patents issued to protect varieties of maize as intellectual property are becoming more common, as is demonstrated in Table 2.

TABLE 2
NUMBER OF U.S. MAIZE VARIETIES PATENTED IN 1986–96

Year	Number of Varieties Patented
1996	23
1995	18
1994	29
1993	2
1992	13
1991	1
1990	0
1989	4
1988	0
1987	1
1986	1

NOTE: Based upon a search of the patent database for years 1976 to 1996 using the keywords "inbred" and "corn" and "line." This search focused on patented *varieties* of maize. Other patents have been issued as well for techniques in breeding and genetic engineering. See the patent database at the U.S. Patent and Trademark Office (1996) Web site.

¹⁰The fact that a patent is valid for 17 years from grant is quite a center of controversy. There has been a movement, supported by the Clinton administration and United States Commissioner of Patents and Trademarks Bruce Lehman, to harmonize United States patent law with that of other nations such as Germany and Japan where the protection is 20 years *from filing*. Congressman Dana Rohrabacher (R-CA) observes: "A biotechnology patent on average takes 10 years to issue. Under the present system the inventor still receives 17 years worth of protection; however, under the proposed change . . . the inventor would only get 10 years worth of protection" (Rohrabacher 1994).

Along with patents, trade secret law has also been applicable to maize varieties since the passing of PVPA. Thomas Boland (1996) explains that unlike patent law, which is protection for a limited time in return for public disclosure of the invention or discovery, trade secrets rights can last forever, as long as the owner takes positive steps in order to preserve the confidentiality of the subject matter. Furthermore, if the invention or discovery is, for any reason, disclosed to the public, then it can no longer be protected as a trade secret. Any type of information can be protected as a trade secret if it is used in business, provides a competitive advantage, and is kept secret. Protection, in this sense, implies that the trade secret is the private property of the inventor or developer, subject to exclusion and exchange as determined by the inventor or developer, as long as he takes positive steps toward confidentiality.

Also, maize seed firms differentiate their product through, as has been noted above, the varieties' different appearances, yields, tastes, resilience to disease and insects, and preferred climate. Firms enhance this differentiation of product through advertising: the equivalent of "peculiarities of the package or container," as Chamberlin (1933: 56) notes. Advertising does more than simply inform. Maize companies seek to create an image of *their* product which singles it out as unique and superior to others. Note the "packaging" of Cargill seed:

From genetic disease resistance in the Philippines, cold tolerance in the mountains of Peru, to drought tolerance in the depths of Africa, Cargill researchers, at over 50 worldwide breeding centers, search for genetics that bring improved hybrids to your farm [Cargill 1996].

Undoubtedly this advertising informs the customer, to a certain degree, about the firm, but observe that the advertising actually says nothing about the product itself, except to imply that Cargill maize seed is different (*better*) than another company's seed.

Maize seed firms even manage to exploit "the general tone [and] character of [their] establishments" (Chamberlin 1933: 56) toward the differentiation of their products. Seeds of Change (1996) touts that it was "founded to foster plant life bio-diversity." Redwood City Seed Company (1996) prides itself in only offering "endangered species" of maize seed for sale. Furthermore, Cargill (1996) likes to remind customers of its "vision . . . to raise living standards around the world by delivering increased value to producers and consumers."

The effective differentiation of products among maize firms suggests that each firm enjoys a degree of monopoly power in regard to their own product(s). Such product differentiation should not be regarded as exceptional, inasmuch as George Stigler (1968: 310) points out:

True, there are (a very few) industries that closely resemble those studied by the economist of perfect competition. True, there are (perhaps more) firms that partake of the nature of monopoly. . . . But vastly more often the firm displays a mixture of insulation from other rivals, by means of real or fancied product differences, and of indirect rivalry by way of (1) the willingness of some consumers to shift among products and (2) the ability of firms to change their products.

Because products are imperfect (granted, often, immensely imperfect) substitutes for one another, and because buyers will switch from one product to another when firms effectively (as Stigler points out, actually or only in perception) differentiate their products from those of other firms, firms can capture a degree of monopoly power and can compete in the industry along margins other than price. As we have said, in the maize market the margins range from the color of the kernel to the socially conscience motives of the maize seed firm.

If every firm in the maize seed industry offered a single seed, differentiated from other firms' seeds through characteristics of both the maize and the firm, then the observations above would suffice. In fact, each firm offers a variety of seeds differentiated from one another and the seeds of other firms. Maize seed biodiversity is realized not simply at the industry level; individual firms are themselves producing biodiversity. But why should individual firms produce multiple products when one differentiated product suffices to attain a degree of market power? The answer is related to the larger issue of why, in general, modern firms exhibit product line diversification.

Risk Aversion and Diversification

Individuals are risk-averse if they dislike an expected loss of a certain amount more than they like an expected gain of that same amount. Such individuals will require compensation for taking on risk. Risk-averse investors reduce risk through diversification of their portfolios, that is "holding several assets or groups of assets, each with a different possibility of loss" (Hadjimichalakis and Hadjimichalakis 1995: 122).

The notion of risk aversion can be applied to firms in the maize seed industry. If a firm acts like a risk-averse investor, it will not offer only one type of seed. The qualities of that variety of maize could fall out of favor with farmers because of the tastes of the farmers' customers, or new diseases and environmental conditions might arise which make the variety useless to farmers. Think of a firm's bundle of product offerings as a portfolio with an overall rate of return (profit) to the firm, and think of each maize seed variety as an asset within the portfolio. If the firm held only one asset in its portfolio, the firm

would open itself to the risk of erratic variability in the portfolio's rate of return. Instead, a maize seed firm can hold numerous and varying assets, which is to say it can offer multiple types of seed. Each variety of seed might draw below-average demand from consumers in a given time period, but other varieties will compensate with above-average demand. In this way, maize seed firms can maintain a product offering that provides the firm with a steady flow of revenue and accounting profit.

It is interesting, however, that product line diversification as described above might only be applicable for those firms having but one shareholder, a private owner. Instead, when a firm has made a public offering of stock and is owned by multiple shareholders who are able to trade shares of the company on a stock market, it is arguably the case that optimal behavior for individual firms is not diversification. Stephen Hymer and Peter Pashigian (1962: 569) point out that "an investor, by picking a random sample of small firms instead of one large firm, can obtain the same average performance and lower variability." When a firm has many shareholders (investors), these individuals, being risk averse themselves, will choose to diversify their own portfolio of firm share holdings. Michael Gort (1966: 40–41) draws the following conclusion from the above observation:

Diversification is often intended as protection against a permanent decline in earnings that could result from a fundamental change in the conditions of supply and demand. With respect to this possibility, a stockholder with sufficient resources has the option of diversifying his investment portfolio, thereby insuring himself against this contingency. From his standpoint, therefore, insurance by a company through diversification may be unnecessary.

Now, more than ever before, with a multitude of mutual funds and other investment pools available to investors large and small, all investors are able to diversify their own portfolios cheaply. Diversification by risk-averse individuals is a tradeoff between expected return and variability of return. If individual investors have it within their own means to diversify against portfolio risk, they have no added desire for the firms in which they hold shares to trade off additional expected return for lower variability.¹¹

¹¹Indeed, diversification by the firm, when it involves developing and from time to time liquidating separate divisions within the firm, can be expected to be costlier than diversification by the investor, which only requires transferring shares in a fluid capital market (Williamson 1975: 144). If such diversification serves only to replace that which could be undertaken by shareholders in a stock market, then it is both unnecessary and unnecessarily costly.

Still, even the large maize seed firms, with shares traded publicly on stock markets, do seem to diversify. Pioneer Hi-Bred, for instance, offered 151 hybrid varieties commercially in 1996, as seen in Table 1. Does this evidence indicate that individual investors still somehow benefit when the firms in which they hold stock diversify their product? Presumably yes, when the multi-product firm has available either economies of scope (i.e., when it is cheaper for one firm to develop and market multiple seed types than to have multiple firms each develop and market a single seed)¹² or capital allocation efficiencies (i.e., when it is cheaper for one multi-product firm to direct the flow of capital internally than to have multiple single-product firms emerge via an external capital market).¹³ The appearance of diversified seed offerings by individual maize seed firms, however, is not necessarily traceable to such underlying economies or efficiencies. Instead, the cause may be an “agency” problem, where existing management entrenches itself in the kind of large and diverse organization that inhibits shareholder monitoring of management (Klein 1998: 13–16). Specifically, managers may seek product diversification to guard against high variability in returns, which jeopardizes their employment in low return periods, because the managers themselves are risk averse.¹⁴

Managers’ interests are not always served best by the course of action which best serves investors; when investors would rather diversify their portfolios themselves, managers could very well prefer to diversify within the firm itself, shielding management against high variability returns. One might argue that the investors could force management to do what is optimal for the shareholders by placing their support or shares behind a unified bid for control of the firm—a takeover. However, Lucian Bebchuk (1985: 1705) writes:

A bid [for a takeover] which would otherwise attract a majority of shares, however, might be impeded under current law by incumbent management’s use of obstructive defensive tactics (such as litigation

¹²For a dissenting view, see Teece (1982). A summary appears in Klein (1998: 8).

¹³Among the efficiencies associated with the use of intrafirm capital allocation rather than the external capital market are: (1) managers already have access to the relevant information by virtue of their routine monitoring procedures whereas such information cannot be costlessly discovered by those external to the operations of the firm; and (2) information divulged in the external capital market about anticipated profitability of a new product line could well induce profit-reducing entry by competing firms into that line (cf. Williamson 1975: 145–47 and Bhattacharya and Ritter 1983). The authors benefited from an application of these notions developed by Klein and Saldenberg (1997).

¹⁴Amihud and Lev (1981), cited in Klein (1998: 13), view diversification through conglomerate merger as a way of reducing the employment risk of managers and find conglomerate merger activity positively associated with several proxy variables measuring managerial autonomy.

or the creation of antitrust obstacles). A self-serving management might currently employ such tactics in order to avoid an acquisition altogether, or to facilitate an acquisition by management's favored acquisition partner.

Also, the U.S. Supreme Court has ruled favorably on the right of state legislatures to erect legal barriers in the way of takeover bids.¹⁵

The current legal environment, itself hostile to "hostile" takeovers, permits managers of some firms to diversify beyond the point that is strictly in the interest of the shareholders. Interestingly enough, if found in the hybrid maize seed industry, this would indicate that publicly traded firms are producing an even greater amount of biodiversity than owners would deem optimal.

So, for which reason do publicly traded firms produce biodiversity in the maize seed market? Are managers developing multiple profitable product lines in the interest of shareholders, or are institutions which inhibit corporate takeovers allowing management to diversify product lines to a point beyond shareholders' interests? Any decisive answer is far beyond the scope and means of this paper. However, considering that corporate takeovers, although regulated and made artificially difficult, do still occur, and considering that certain incentives have been developed to entice management to act in the interests of investors (e.g., stock options), a reasonable conjecture seems to be that both reasons may have an influence in part. In any case, the incentives for product line diversification, whatever their origin, lead to enhanced biodiversity created at the level of the firm.

Conclusion

Walter Block (1990: 281) expressed the belief that: "A reconciliation between economics and [the environmental movement] can be accomplished by using the institutions of the former as a means of attaining the goals of the latter." In addressing the concerns surrounding the issue of preserving and enhancing biodiversity, we hope to have reconciled knowledge of market forces and environmental awareness. We have argued that biodiversity, to the extent that it is desirable, is a good that can be provided by self-interested participants in the market. Concrete examples document both the direct market provision of

¹⁵In *CTS Corp. v. Dynamics Corporation of America* (1987), Dynamics Corporation challenged an Indiana law which "provides that the acquisition of 'control shares' in [a corporation] . . . does not include voting rights unless a majority of all preexisting disinterested shareholders so agree at their next regularly scheduled meeting." The Court held: "The Indiana Act protects independent shareholders from the coercive aspects of tender offers by allowing them to vote as a group."

biodiversity and its indirect occurrence as a natural byproduct of commerce. And our examination of the maize seed industry reveals substantial biodiversity, not only at the aggregate industry level but at the level of the individual firm as well, a finding consistent with rudimentary considerations of monopolistic competition and diversification.

Since the time of Adam Smith, it has been recognized that self-interested actors are often led by an invisible hand to undertake private actions that yield desirable social outcomes which are no part of any individual's intention. Concerning the portion of our analysis highlighting the indirect market provision of biodiversity, we have in essence proposed and defended a Smithian corollary: biodiversity is frequently an unintended yet desirable consequence of market forces.

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