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Value-adding partnerships in proprietary value-enhanced specialty grain: A case study of High Oil Corn

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Value-adding partnerships in proprietary value-enhanced specialty grain:

A case study of High Oil Corn

By

Wenying Du

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To

my husband, Bin, for his support and patience

my parents, for giving me a good education

my grandparents, for their love and protection

my sisters and brother, for always loving each other

You are both my strength and my weakness

for I love you all so dearly.

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ABSTRACT

This dissertation examines the value-adding partnership in commercializing a proprietary value-enhanced specialty grain - DuPont's High Oil Corn, analyzes the decision-makings along the value chain, and explains the governance structure of the value-adding partnership from the perspective of the theory of firm. It argues that private investment efforts play an important role in determining the governance structure, and the governance structure evolves with the evolution of the importance of those efforts.

CHAPTER 1

INTRODUCTION

Traditionally, agricultural products have been produced and traded as generic commodities. Grains are loosely classified in several grades based mainly on their physical attributes. Products from different farms lose their identities as soon as they enter marketing channels. They are co-mingled with products from other sources. Producers are anonymous. End-users simply accept what they get and have no idea where the supplies come from and nor does that matter, although final products processed from agricultural raw materials are often varied and differentiated.

Despite the dominance of commodity production in the grain industry, there has always been an effort to produce a differentiated product that meets a specific need. Such are specialty grains. A specialty grain has intrinsic attributes that best meet the requirements of a particular group of customers, and can improve either production efficiency or end product quality. The identity of a specialty grain matters. It is almost exclusively traded out of the commodity system.

Increasingly, the grain industry today is moving from a pure commodity focus to a quality value-added focus driven by technological innovation and value-seeking of all parties involved. As concerns for production efficiency and food safety are mounting, end-users are increasingly interested in the quality and specific characteristics of the inputs they are using or consuming. But, the customization of agricultural production to its end-users has only taken off with the revolution of biotechnology.

In the grain industry, genetic engineering has focused for years on developing input-specific traits such as herbicide-resistance and insect/disease resistance. In 1996, the first crop seeds improved through biotechnology became commercially available to growers in the U.S. (Cline and Esfeld, 1998). Among those that have achieved high commercial values are Bt Corn and cotton and Roundup Ready Soybeans and Cotton (Hayenga, 1998).[1] However, some plant breeders have shifted their focus to develop output-specific traits that are selected, designed and grown for a specific group of customers and provide more value than their commodity counterparts in terms of productivity. These products are called value-enhanced grain, or specialty grain to be distinguished from their commodity counterparts.[2] There are a number of products in the pipelines from several firms including high lysine, methionine, and tryptophan corn, and high oleic, low linoleic soybean oils and others (Hayenga, 1998). High Oil Corn is a successfully commercialized value-enhanced corn on the market. Although it is not genetically modified, it does share an important attribute with other genetically modified value-enhanced grains- the seed technology is proprietary. In fact, this new generation of hybrids is characterized by their patented genetic sequences or processes that have legal protection for a fixed period of time. Private firms are the leading force in this revolutionary innovation and hold the intellectual rights to the products they have created or bought. For example, the High Oil Corn seed technology is owned by DuPont, different forms of Bt Corn seed technology are separately owned by Monsanto, Dow, Novartis and AgrEvo, and the technology used to produce the popular Roundup Ready seeds is a property of Monsanto (Hayenga, 1998).

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[1] Bt Corn (*Bacillus thuringiensis*) is resistant to European corn borer and Roundup Ready seeds are resistant to herbicide Roundup.

[2] *Value-enhanced grain* and *specialty grain* are used interchangeably in this paper.

Biotechnology firms have invested substantially in R&D to bring the new product to the market, and to capture the value of their innovation is vital to their long-term survival. The crops with genetically enhanced input traits such as Bt corn and Roundup Ready soybean are accepted by growers quickly, but the commercialization of value-enhanced grains faces more challenges due to the lack of established markets.[3] Success in the commercialization of these proprietary value-enhanced crops hinges on the creation of a market for the new products, which requires close coordination among the players along the value chain. We call these relationships "value-adding partnerships". There has been considerable restructuring in the agricultural sector in order to develop and enhance such partnerships. We examine a special case – High Oil Corn in the hope of shedding some light on potential changes in the market for other genetically modified value-enhanced grains.

This dissertation is organized as follows. Chapter 2 provides a detailed description of the value chain of a proprietary value-enhanced grain- High Oil Corn (HOC) and its value-adding partnerships. Chapter 3 reviews the literature on specialty corn and general literature on value-adding partnerships. Chapter 4 presents the theoretical models. Empirical evidence is discussed in light of the models in Chapter 5.

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[3] Bt Corn was introduced in 1996 and captured 1% of the corn acreage in that year, and attained 20% of the corn acreage in 1998. For Roundup Ready soybean, the acreage percentage was 1% in 1996, and 37% in 1998. For Roundup Ready cotton, 6% in 1997 and 28% in 1998. High Oil Corn, in contrast, was introduced in 1996, but attained 2% of corn acres in 1998 (Hayenga, 1998). However, Genetically Modified Organizms (GMOs) face more opposition in Europe.

CHAPTER 2

PROPRIETARY VALUE-ENHANCED GRAIN AND ITS VALUE-ADDING PARTNERSHIPS

2.1 A Proprietary Value-enhanced Specialty Grains-High Oil Corn

Corn is processed for consumer products, energy, sweeteners, starch, proteins, oils, animal feeds and other uses. Different users have different preferences for input characteristics. Corn wet millers prefer soft-textured, thin perocarp kernels, while corn dry millers want hard-textured kernels, and feed users like corn that contains more oil. In the late 1960s and early '70s, a specialty corn, high lysine corn, was produced and identity preserved for livestock use. Today, the most common specialty types are high oil, white, waxy and high-amylose corn, and the most successfully commercialized using proprietary technology is the Optimum High Oil Corn (HOC).

2.1.1 What is HOC?

HOC is directed at the animal feed industry. The single biggest use of corn is as an animal feed ingredient. Over 60% of the corn consumed within the U.S. is fed to animals and so are most of the exports. Overall, an estimated 80% of corn produced in this country is used as animal feed. Corn is a major ingredient for virtually every species of livestock. Two crucial traits for quality improvement in this use are higher energy and improved protein quality (Renkoski, 1997). The typical yellow dent corn on the market, with an average 4% oil content, has to be supplemented by more expensive and concentrated ingredients such as

fat, high protein concentrates, and synthetic amino acids in a typical ration to optimize performance. HOC is modified to contain a high level of oil. With 7.5% oil content on average, it can be used to substitute for animal fat and a portion of the soybean meal in a typical ration, and allows livestock producers to increase feed efficiency (Optimum's website)[4]. HOC is more valuable as an animal feed ingredient than commodity corn.

2.1.2 History of Optimum HOC

Dupont first became interested in HOC in 1986, although research on it had begun long before (Renkoski, 1997). Through a research and commercialization program with Holdens Foundation Seed Company, Pfister Hybrid Corn Company, and a number of other collaborating hybrid corn companies, Dupont developed and marketed high oil corn under the OPTIMUM brand (Feedstuffs). It bought out all business and technology rights to HOC from Pfister Hybrid Corn Co. and Holden's Foundation Seeds on Feb. 18, 1996 (Feedstuffs, March 3, 1996), and became the sole owner of HOC technology.

On Jan 1, 1996, Dupont and a leading seed company, Pioneer Hi-bred International, set up a joint venture called Optimum Quality Grains to discover and develop quality-improved grains, of which HOC is a major product. Dupont had licensed its technology to 58 seed companies to produce HOC seeds by 1997[5]. In August 1997, Dupont announced a plan to invest $1.7 billion for a 20% percent stake in Pioneer (Agri Marketing), and it promised to honor its agreements with other seed companies that market Optimum HOC, although Pioneer would be the preferred supplier. Growers sign a contract with Dupont to

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[4] See Appendix 3 for more about the value of HOC.
[5] The high oil line characteristic is concentrated in an inbred line that DuPont supplies as the male pollinator with male sterile high yielding strains of corn.

buy seeds from licensed seed companies. They can produce HOC for their own feed uses, or

for contracts with designated elevators. Subsequently, in March 1999, DuPont acquired

Pioneer. DuPont bought out the 80% equity stake in Pioneer that it did not already own, and

Pioneer became an independent subsidiary wholly owned by DuPont. The joint venture,

Optimum Quality Grains will be a wholly owned subsidiary of DuPont as well (SEC Filing,

1999).

2.1.3 Export of HOC

A big market for HOC is overseas; demand in Latin America, Asia and Middle East

is growing. The U.S. exports 20% of its corn crop and a significant amount of value-added

products every year. As a substitute for oil, HOC is even more appealing overseas, where fat

is relatively more expensive than in the U.S. or forbidden to be used by some religions. Fat

is cheap in the U.S as a by-product of a huge livestock industry, but transportation costs

makes it undesirable to export. In early 1996, Dupont formed a partnership with Continental

Grain to market HOC overseas (Feedstuffs, 1996) and to "develop efficient value chains to

assure customers of a consistent, dependable, and high quality supply tailored to their needs"

(Hammes, 1996). In about five years, production of HOC grew from virtually zero acres in

1993 to approximately 900,000 acres planted in 1998 and 1.25 million acres estimated for

1999 (Reuters, 1999). Dupont entered into contracts with growers to produce Optimium

HOC for export markets on approximately 150,000 acres in 1996 out of 300,000 acres

actually planted in that year. Acreage for export in 1997 was estimated to approach 350,000,

which will produce approximately one million tons of high oil corn and accounts for half of

the total production (700,000 acres) contracted with Dupont (OPTIMUM University, 1997).

When Continental Grain's grain business was bought out by its rival- Cargill- in late 1998, Optimum Quality Grain discontinued its agreement with Continental. As a result, on June 1999, Optimum Quality Grain entered into marketing agreements with Archer Daniels Midland (ADM) and ConAgra Trade Group to manage the growing export demand for Optimum HOC (Feedstuffs, 1999). Currently, Optimum has three grain exporting partners- Consolidated Grain & Barge, ADM, and ConAgra Trade Group.

2.2 Value-adding Partnerships (VAP) in General

A value-adding partnership is defined as "a set of independent companies that work closely together to manage the flow of goods and/or services along the entire value-added chain" (Johnston and Lawrence, 1988, P.94). A value-added chain refers to the various steps a good or service goes through from raw materials to final consumption. The transactions between stages in the chain are traditionally carried out either by an arm's length market or by hierarchies of common ownership, while intermediate governance forms exist between two adjacent stages. Williamson (1991) describes these intermediate forms that lie on the continuum between market and hierarchy as hybrid. A VAP, usually accomplished by contractual relationships, is one of the hybrids. It provides close coordination among all members of the value chain, but falls short of vertical integration.

2.2.1 Contract production

In the case of specialty grains, VAP is almost the only observed organizational form governing the processor and grower relationship. Contract production has been the norm for specialty grains.

Specialty grains can potentially add value to users and end processors, but achieving that value requires the preservation of identity, otherwise the value will be diluted or lost when mixed with other corn that doesn't have these special attributes. The current grain handling, transporting and trading system is organized to efficiently move large quantities of relatively generic commodities over long distances. Specialty grains are targeted at quality traits that are not yet measured in standard grades but which have a substantial impact on the grain's value for a particular user. The volume of specialty grains is relatively small, making the cost of segregating them within the current system very high, sometimes, prohibitively so. This poses a huge challenge for production and marketing. Without a guaranteed marketing channel, growers are hesitant to grow a specialty grain without a buyer, particularly when the grain has limited uses or a promised price premium if its yield is lower than normal grain and/or seed price is higher. The management of an identity-preserved system with small volume requires an industrial structure that is different from that of commodity production. Without such a system, the added value of specialty grain won't be realized. When a large volume is achieved, a specialty grain becomes a "super-commodity", and it can be managed as a different variety of grain just like other traditional commodities.

As a result, a contract production system is used for specialty grain with small volumes that fall short of being a "super commodity". At the beginning of the production season, processors offer contracts to growers for them to grow certain specialty grain for them at some price premium above the open market commodity price. This has been done between domestic users and growers.

2.2.2 Alternative Arrangements

As explained before, it is difficult for specialty grain to be exchanged through open market transactions due to small volume, diseconomy in handling, and the small number of buyers. A successful farm operation still requires close, personal supervision and skill. This creates obstacles for nonfarm processors who wish to vertically integrate into grain production (Kohls and Uhl), due to monitoring costs associated with moral hazard. Besides, there are possibly financial constraints, and /or legal constraints, let alone farmers' resistance. Vertical relationships based on trust or reputation are much talked about in the literature, but ones involving specialty grain growers are not observed. Trust is hard to establish when many small players are involved. That specialty grain contracts usually last for only one planting season makes it even harder.

When more players are incorporated into the value chain, as is true with proprietary value-enhanced grains, contractual relationships get more complicated. Partnerships in the forms of alliances and agreements, joint ventures, or outright ownership emerge as the sector evolves. These relationships differ in the degree of control and coordination. Ownership confers the largest amount of control and makes maximum coordination possible. Partners share control and coordination over joint ventures and close coordination can be achieved. Control over alliances is rather weaker, but the degree of coordination is still much higher than through the arm's length market, especially when the relationship is intended to be long-term. In relationships between large established firms, reputation and trust may play some role, but they cannot safeguard opportunistic behaviors to such an extent that governance structures are no longer important when contracts are incomplete.

2.3 Value-adding Partnerships in HOC

2.3.1 The Value Chain of Proprietary Specialty Grain and Exporting of HOC

As Renkoski (1997) and other industrial experts point out, the value chain for proprietary specialty grains consists of trait developer, seed companies, growers, evlevators and grain companies, and end-users. At the beginning of the chain is trait development. This includes the technology available to seed companies to develop new seed products. Next, grain farmers convert the seeds into value added grain, while elevators that are owned by the exporting grain companies serve as a collection and storage point for the grain. Grain and transportation companies move the grain to processors who convert it into value-added food, feed, or industrial products[6].

For the value chain of HOC export, Dupont is the technology provider, seed companies produce seeds using Dupont's technology, and the growers buy the seeds and produce the grain. Elevators and grain firms channel the identity-preserved grains to the end-users (See Figure 1).

2.3.2 Decision-making along the Value Chain

The value-added chain works only if all the parties cooperate. Obviously, all of them have outside options and can choose to trade with others. Therefore, the system is viable only if everyone gains more by participating than otherwise, and the prerequisite is that there exists net added value compared with commodity corn, namely, the added value to end users minus the added costs of producing and marketing is positive. As mentioned above, the

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[6] The value chain is shorter for growers who feed the grain to their own livestocks where no elevators or grain companies are needed to complete the transaction.
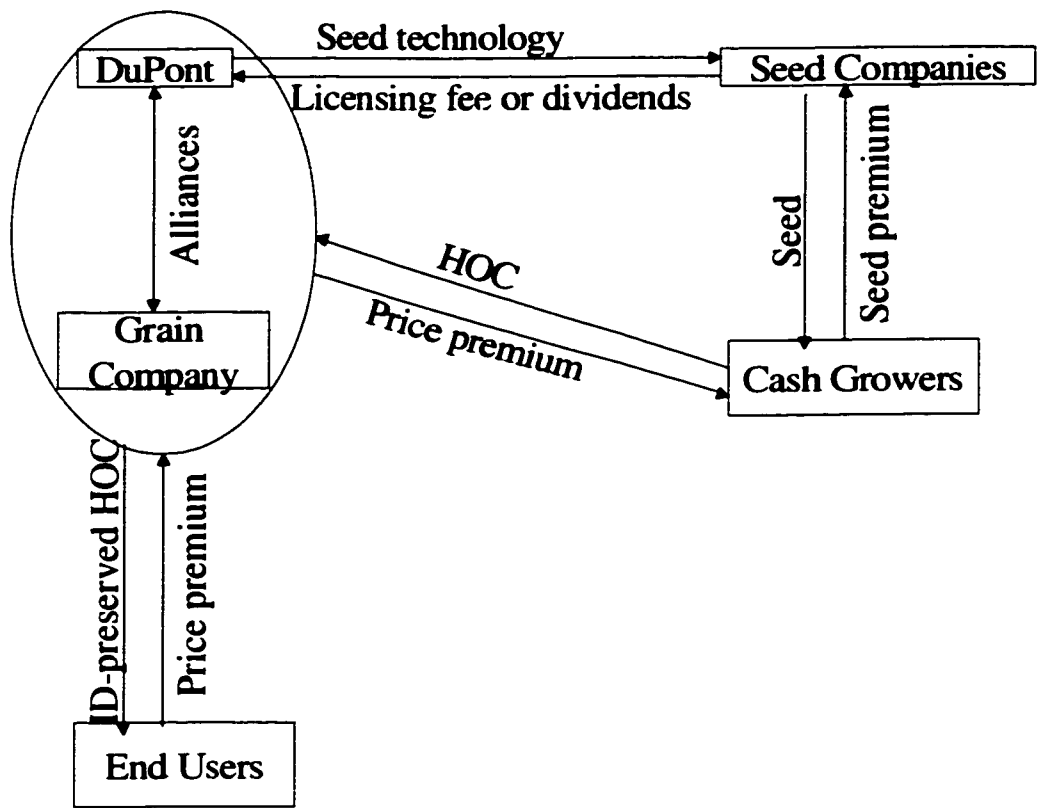
Figure 1: The Value Chain of HOC Export

marketing cost for specialty grain is higher than for commodities. On the production side, stacking genetic traits onto the seeds often drags down yield. To keep the specialty grain separated during the growing, harvesting, and storing adds cost on the farm as well. Let's evaluate each party's decision separately.

Dupont: Dupont is the technology provider. The technology would be useless if not commercialized. The goal for Dupont is to capture as much value as the technology can produce so as to recover the sunk and continued cost of research and development and to make a profit. Potentially, it can sell its technology to an outside party, or retain ownership and participate in the later stages of value creation through licensing or direct production. Dupont has chosen the latter. "We work to create new grain production, identity preservation and marketing systems to deliver and capture the added value we've created. ... Delivering and capturing value is just as important as creating it, so our goal is to do both in tandem," said Hammes, a manager at OPTIMUM Quality Grain, on the launching of company in 1996.

Seed Companies: These firms, if they choose to buy or license technology from Dupont, are intending to collect a price premium for their seeds to compensate for the production costs incurred and the license fee paid to Dupont. Strategic goals like capturing market shares are also possible. Complications such as interbrand competition might arise too.

Growers: They can be divided into two groups. One group produces corn for its own feed use, the other for adding income. For the first group, the producers are also end-users, no marketing channel is needed and no marketing cost is incurred. As long as there is a

benefit, HOC will be produced. For the second group, a price premium should be guaranteed before production is started when there is yield drag and more variability. Because end users and growers are geographically dispersed, the probability that growers will sell HOC at a price premium to the right customers on the open market is very low after harvest[7]. Besides, the verification of the grain's intrinsic characteristics is another issue. Therefore, for this group of growers to participate, a contract production system is needed, which is what we actually observe. A regional market can develop between cash growers and their neighboring feeders, but contracts are still needed to safeguard opportunistic behavior. To determine the terms of contracts, the net returns that a grower anticipates from alternative crops will form the lower limit of what he will accept to produce HOC. Notably, most contracts for specialty grains including those for HOC, guarantee a fixed premium added to the spot market price of commodity grain at the time of transaction rather than a fixed future price. Theoretically, growers can always use the well-developed future and option markets to manage the commodity price uncertainty.

Elevators and Grain Companies: They are the connecting points between the second group of producers and end-users. Their function is to buy HOC from producers, to preserve its identity and to deliver it to the particular targeted users. During the introduction period, when users are not familiar with the new product, considerable marketing efforts are needed to create a market. To identity preserve HOC, investment in additional capacity (dedicated asset) has to be made in some cases[8].

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[7] Breakthroughs in communications like internet help to lessen the matching problems between growers and end-users, but can't solve the problem completely.

[8] Continental renovated its facility at E. St. Louis to provide direct loading of value-added commodities, such as high oil corn and other specialty grains. *Feedstuffs*, 1996

End-users: They are the ultimate source of value creation. The new product, HOC, with superior quality, is compared to its closest substitute- typical grade 2 yellow corn, and other feed supplements such as fat. Given all the prices, a feed ration is optimized to minimize cost per pound of weight gain or maximize breeding and reproduction performance. In the milling process, equipment that is specific to processing HOC has to be bought and employed. For example, Gold'n Plump poultry, opened a new feed mill in Arcadia, Wisconsin which was specifically built to handle high oil corn and other specialty grains in 1997.These are also relationship-specific investments. Because of this fixed investment, a certain level of scale and continuous supply has to be guaranteed to make the use of HOC economical. Consistent quality of the supply is another key for the acceptance of the new product.

2.3.3 Industry Structure

As the sole provider of technology, Dupont is no doubt a monopoly and has the market power to maximize its gain, but this power is weakened by the lack of an established marketing channel, which calls for the cooperation of grain companies to create a market for HOC. Competition also comes from substitute products such as commodity corn and fat, a byproduct from many food processing operations.

The past couple of years have witnessed much consolidation of the seed industry and even more is likely. By late 1998, most seed companies of significant size and/or with biotech assets had been acquired or aligned with large chemical firms (Wall Street Journal, Sept. 29, 1998). The seed market is dominated by a handful of big firms, though there are still a number of small independent seed firms spread across the mid-west. Pioneer and

Monsanto control more than half of the North American Seed Corn market, with Pioneer having more than 40% of the market share. (Hayenga, 1998) The seed market can be characterized as two or three market leaders with a number of followers. With the acquisition of Pioneer, DuPont can virtually set the premium for HOC seeds directly through Pioneer and indirectly via license fees it charges other seed firms subject to the participation of other parties along the value chain.

Growers, traditionally small, and large in number, are competitive price takers. They do not possess market power either in obtaining seeds and others inputs, or in bargaining with elevators. But they do have alternatives to producing HOC.

Local elevators are geographical monopolies, but competition is intense. Major grain companies have elevators spreading across the grain belts. Exporting grain companies face competition from others, but at the introductory stage, the small volume of HOC can not supply a large number of firms with a sufficient quantity to obtain their efficient operating levels. Very likely only one or possibly two such firms can exist in the market. Together with elevators, grain companies can set the price premium of HOC, subject to the participation constraints of growers and end users, if no objection comes from Dupont. The corn market is competitive with a large number of sellers and buyers, as are most feed supplement markets. The value of HOC will ultimately be determined competitively by its quality and the prices of its substitutes. The price of HOC to end users (processors), on the other hand, will be bargained upon when only a handful of big buyers are involved and specific equipment is needed to process HOC.

What we observe: DuPont formed an alliance and then acquired one of the biggest seed companies- Pioneer HiBred International. It has licensed its technology to a number of

seed firms. It signs production contracts with growers to use seeds from designated seed

firms, and worked with Continental Grain and later on with others to market HOC overseas.

DuPont also formed a joint venture with Pioneer-Optimum Quality Grain to market HOC

and other value-enhanced grains overseas, which is wholly owned after the acquisition of

Pioneer. In this value chain, all the parties are connected with contracts or agreements

except the link between growers and seed companies (See Figure 2).
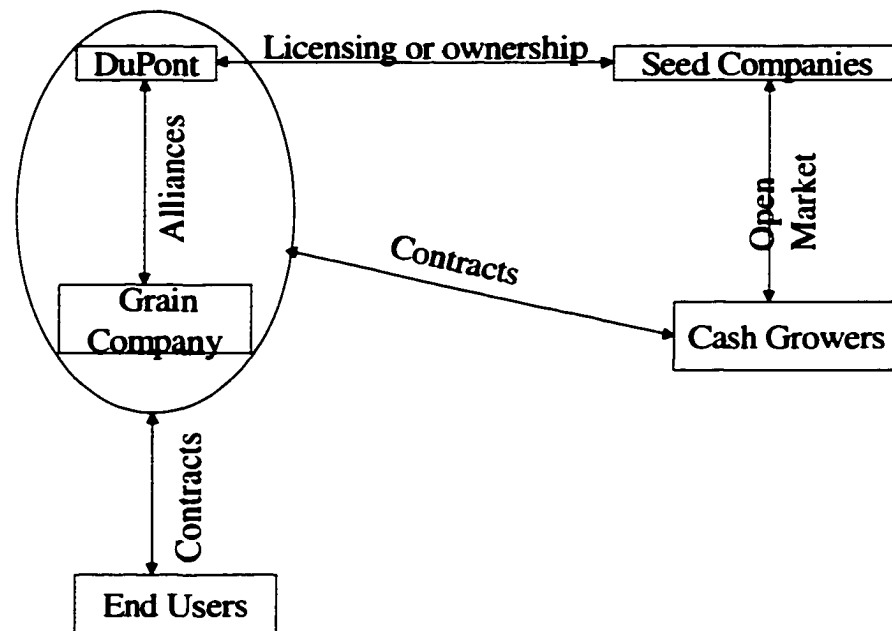
Figure 2: The Structure of the Value Chain of HOC Export

This structure of the HOC value chain is closely related to the fact that HOC is a new

differentiated product produced with privately owned technology aimed at a specific niche

market. With relevance for similar products that have or will come out in agricultural and

other industries, it will be interesting and rewarding to look into the nature of the contractual

relationships among the parties involved in HOC. This is especially true, when research in agricultural development is shifting from public funded institutions to privately owned firms, and private firms are at the forefront in the ongoing wave of commercializing biotechnology in the agricultural production. Although biotech has come under criticisms and there are increasing attention on the controversies of genetically modified organisms (GMOs), we expect that research and developments will go on in this field and new products will be introduced in the future as we learn more about the GMOs.

2.4 Recent Restructuring in the Agribusiness Sector

Besides the emerging of value-adding partnership in exporting proprietary value-enhanced grains such as HOC, there has been considerable restructuring among the players along the value chain. The restructuring includes mergers and acquisitions among the chemicals, biotech and seed firms, the split between drug and agribusiness, alliances established between biotech firms and grain companies and consolidation of the grain companies[9].

Consolidation between chemicals, biotech and seed firms: The consolidation between chemical giants, biotech firms and seed companies is characterized by mergers in the chemical and biotech sector and their subsequent acquisition of seed companies. By late 1998, "most seed companies have either aligned themselves with, or been acquired by, crop-biotechnology juggernauts such as Monsanto Co., DuPont Co. and Dow Chemical Co." (Wall Street Journal 9/29/98) A seed firm, Cargill, which didn't have access to biotechnology and the new genetic products produced by it, tried to sell its domestic seed

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[9] See Appendix 1 for a detailed report on the activities of individual firms.

business to AgrEvo and its international seed business to Monsanto (Heffernan). Now, there are hardly any significant independent biotech assets left in this sector. In the meantime, the leading global biotech firms have obtained access to the seed market through merger and acquisitions.

We observe:

- Most major acquisitions of seed firms occurred after 1996 when the first seeds with input traits modified by biotechnology started to be commercialized.

- Most major acquisitions followed previous collaboration relationships such as joint ventures, research partnerships, and minority equity investment by biotech firms in seed companies. (DuPont/Pioneer, Monsant/Dekalb, Dow Agrosciences/Mycogen)

- No seed firms of significant size are now independent of big biotech and chemical firms.

- Seed firms were acquired by biotech and chemical firms, not the other way around.

That the consolidation and commercialization of genetically modified products occurred around the same time is no coincidence. The seeds with genetically modified input traits have made a big impact on the crop protection products, and will continue to do so in the future. According to Hayenga (1999), the acreage treated for European Corn Borer in 1998 dropped by approximately 2 million acres, a 30% reduction from the previous year, due to low ECB population and the substitution of Bt Corn varieties. The number of soybean acres treated with Roundup doubled in 1998, with most competitors having their market share drop by one-third to one-half. Thus the impact of biotech seeds on the chemicals is twofold. The insect-resistant seeds such as Bt products reduce the need for chemical treatment and thus the demand for the correspondent insecticides. These seeds serve as a substitute for chemicals. The herbicide-resistant seeds such as Roundup Ready products

increase the demand for the resisted herbicide, but reduce the demand for non-compatible herbicides. These seeds are complementary products of certain chemicals, but foreclose the use of other non-compatible products.

Biotechnology must be combined with seed technology to successfully develop a new generation of seeds. In cases the biotech firms choose to participate in the creation of a value-enhanced grain market, the seed firms' extensive distribution network is very valuable. Therefore, the biotech, chemical and seed technologies become increasingly complementary.

Most acquisitions followed a previous collaboration relationship. For instance, before DuPont bought out Pioneer, it had a research alliance agreement with and equity investment in Pioneer. The reason for the acquisition was that, as the proxy for the merger says, "the need to obtain the mutual consent of our two organizations to pursue opportunities and differences of opinions as to how to divide the costs and rewards of these opportunities were hampering our ability to develop new products as efficiently as possible." (SEC Filing 13E3, P.1)

Split between drug and agribusiness: After the flurry of mergers between drug and agricultural biotech firms to create a "life-science" conglomerate in the earlier years, there is a trend going in the reverse direction-some firms are splitting their pharmaceutical and agribusiness.

Wall street analysts and economists cite the reason for the spin-offs is that agribusiness seemed not to offer synergies with the other healthcare divisions. The life sciences strategy, that marries fields such as biotech drugs, nutrition and agriculture to seek synergies from businesses ranging from farming and livestock to drugs and human nutrition,

does not seem to pay off. The agri-biotech assets and pharmaceutical assets are not as complementary as was originally thought.

Alliances between biotech firms and grain companies: Several biotech firms have formed alliances with grain companies to create markets for value-enhanced grains. The alliances between biotech and grain companies are generally in the form of joint ventures and marketing agreements. Outright acquisitions of grain companies by biotech firms are not yet seen.

Consolidation of the grain companies: Joint ventures and acquisitions are common among grain companies as well. Mergers and acquisitions (M&A) in this sector increase the market power of the resulting firms without significantly increasing or decreasing employees' incentives. The physical assets that provide economies of scale and scope may be more important than the human assets. And economies of scale and scope may be the main reason for the consolidations in the grain sector.

Biotech firms integrate into downstream- grain processing: There is not much direct integration by biotech firms into grain processing sector, although biotech firms such as DuPont believe that it is important for them to work with end-users to gather information on the specific demands of customers[10]. However, integration by grain companies into processing are much more common.

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[10] DuPont did acquire Protein Technologies International, a supplier of soy proteins to the food and paper processing industries in December 1997.

CHAPTER 3

LITERATURE REVIEW

3.1 Previous Literature on Specialty Grain Production

Historically, contract production, or any other sort of vertical coordination in the grain industry has been limited, except forward contracting of prices, and contracts with the federal government to participate in price and income support programs, along with acreage set-aside agreements (Lajili, et. al., 1997). These programs provide a means of risk management. But specialty grain production has always relied on contractual arrangements. These arrangements are usually written or oral agreements between a producer and a specialty crop end-user (or supplier to an end-user), established prior to the production season. In addition to quantity, price and some general or industry standard quality level, these contracts often specify inputs such as the variety of seeds and production practices to be used by the supplier. The processor is actually taking some control over the supplier's production practices through the contracts. Changes in government programs and consumer demand, aided by new technologies, are leading to more specialty crop production, and as a result, contract production (Coaldrake and Sonka, 1993). Contracts have been used more frequently in fruit and vegetable products.

Theoretical studies on specialty corn or grain production per se are scarce, as specialty grain production itself has been. Earlier studies focus on its risk and return aspect. Kliebenstein and Hill's (1971) paper on corn high in Amylopectin or Amylose starch which

was contract produced and identity preserved for firms manufacturing starch is an example. They compared returns from alternative contracts at various price levels.

There are several more recent empirical papers stimulated by renewed interest in specialty crops. Coaldrake and Sonka (1993) explore characteristic and attitude differences among contracting high-value crop producers and non-contracting producers. They used a survey sample of East Central Illinois farmers and found that contracting producers are younger and better educated, with fewer years of farm experience, but farm and rent more acreage than non-contracting producers.

Farmers' preferences for crop contracts are studied by Lajili and others. Their approach is an empirical one that combines elements of principal-agent theory and transaction cost economics. They hypothetically offered farmers a range of contracts that differ in uncertainty and level of relationship-specific investment, and observe which one was chosen. The statistical results from the experiments indicate that asset specification and uncertainty, along with selected business and personal characteristics significantly influence farmers' preferences for contractual arrangements, as one would expect from transaction cost theory.

Weleschuk and Kerr (1995) also employed the transaction cost approach. They studied the sharing of risk and returns in prairie special crops in Western Canada. Farmers have a choice of either signing a production contract with a buyer prior to planting the crop, or selling the crop after harvest to a limited number of buyers. An open spot market does not exist due to the small number of buyers and sellers. The contracts in use are shown to give more power to buyers than to sellers. Ex post bargaining is not efficient due to the information disadvantage of farmers and the poor prospect of alternative-traditional prairie

crops. Farmers receive less return from their investments and thus invest less than the efficient level. The authors suggest that government intervention aimed at providing information to farmers is desirable to improve efficiency.

A number of papers study the impact of biotechnology on the structural changes in the agricultural sector. Shimoda (1998) notes that the combination of "the technology and delivery vehicle" such as biotechnology firms and seed firms and "commercialization structure" such as marketing and distribution channels is essential to the success in the commercialization of agricultural biotechnology. As a result, "multi-dimensional vertical and horizontal linkages" will form "agricultural industrial complexes". Heffernan (1999) uses the "cluster of firms" to represent the new economic arrangements in the food and agricultural system. He predicts that four or five food chain clusters that control the food system from gene to supermarket shelf will emerge and compete against each other. Lerner and Tsai (1999) examine the contract structure of the alliances within the biotechnology sector. They found that contract structure does matter and those designed consistent with the theory perform significantly better.

3.2 The New Theory of Firm

The agricultural industry, as a whole, has witnessed increasing vertical coordination and product differentiation at the farm level, which is seen by some as "the industrialization of agriculture" (Hurt, 1994). The undifferentiated products and open markets characterizing many agricultural commodity markets are evolving toward the differentiated products and the contractual or integrated or controlled-supply markets that have typically characterized the manufacturing sectors of the economy (Sporleder, 1992).

The new theory of firm, transaction cost economics (Coase, 1937; Williamson 1979,1985) and incomplete contracting and property rights analysis (Hart, 1995) in particular, provide a new framework other than the traditional production function approach to understand this dramatic structural change.

The transaction cost theory, which started with Coase's famous 1937 paper and extensively developed by Williamson and others, views a firm as a governance structure rather than a production function. So the "boundary of the firm is no longer defined by technology but is something to be derived from comparative transaction cost considerations" (Williamson, 1994). Transaction costs arise because of bounded rationality, opportunism, and asset specificity. In a complex world full of uncertainty, it is impossible to anticipate all the contingencies possible in the future. Therefore, long term contracts are inherently incomplete. Safeguards are needed because economic agents tend to behave opportunistically and seek self-interest whenever possible. Opportunism in the presence of transaction specific investments or "appropriable quasi-rents" as referred to by Klein, Crawford, and Alchian (1978) will lead to the hold up problem, which is a leading factor in explaining the existence of vertical integration. To safeguard a transaction against opportunistic behaviors requires credible commitments at the beginning of a contractual relationship. Choices of governance structures are viewed as farsighted response to the ex post hazards of opportunism in a world of long-term, incomplete contracts implemented under uncertainty.

The transaction cost theory implies that there is less haggling and hold-up problems within a merged firm, but it doesn't provide an answer to why (Hart, 1995). The property rights theory, on the other hand, attempts to answer this question. According to the property

rights approach, ownership of physical or nonhuman assets matter when contracts are incomplete. Ownership confers the residual control rights of the assets and is a source of power when it is impossible to write a verifiable contract that could be enforced in a court of law and specifies the efforts or outputs of the parties involved. Therefore, ownership is a scarce resource that must be allocated optimally to maximize the surplus from any economic relationship. The theory argues that ownership structures affect the efforts of the contracting parties, and it is generally optimal for ownership of assets to be assigned to the party with the greatest marginal ability to affect the outcome.

The foundation of property rights theory-incomplete contracting has been challenged (Che & Hausch, 1999; Hart & More, 1999). Maskin & Tirole (1999) attack its lack of rigorous foundations by developing a number of irrelevance theorems that show contracts can be designed to overcome ex ante indescribability of trade. But Hart & Moore (1999) counter with a model providing a foundation for the idea that contracts are incomplete. Several authors argue that some carefully designed contacts can solve the holdup problem that plagues relationship-specific investments. Examples are Chung (1991) and Aghion et al. (1994). However, Che & Hausch (1999) criticize these works for assuming the ex ante manipulation of bargaining power. Furthermore, they show that when the relationship-specific investment is sufficiently cooperative in the sense that the investment generates a direct benefit for the trading partner, there exists an intermediate range of bargaining shares for which contracting has no value; and all contracting becomes worthless in improving

efficiency when both investments are purely cooperative[11]. Therefore, even if contracting

can safeguard some selfish investments, cooperative investment must be safeguarded by

organizational arrangements such as allocating property rights.

A number of researchers have explored the implications of the modern theories of

the firm for the evolving agricultural sectors (Barry et. al., Splorleder, Schrader, Knoeber,

and Frank and Henderson, and others). They have primarily focused on the reasons

underlying the increasing vertical coordination within the value-added chain. Theories of the

firm are rightly resorted to a tool of analyses. Vertical coordination is studied as an

alternative to open market transactions.

3.3 Relevance of Previous Literature to High Oil Corn

The HOC system and specialty grains in general are part of the industrializing trend

in agriculture, as far as product differentiation and closer ties between vertical stages are

concerned. However, coordination forms vary across different sectors, ranging from

minimum to complete common ownership. Contracts, generally referred to as any form of

vertical coordination that falls short of common ownership control, differ greatly in the

number of decisions influenced by the contract, the sharing of costs and risks, and the

specificity of the terms. For instance, forward price contracting in grain, cattle, and hogs

specifies some of the product characteristics that will be acceptable and the basis of

payment. Neither party exerts much vertical control. Such contracts are called market-

specification contracts. Contracts in specialty grain often specify certain production

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[11] Che & Hausch define cooperative investment as the investment made by one party that generates a direct
benefit for its trading partner. Those that only benefit the investing party are called selfish investment. The
cooperative investment is "pure" when it has no (or negative) accompanying direct benefit on the investing
party. (Che & Hausch, 1999)

resources (such as seeds) to be used and sometimes producers get managerial help and supervision from contract providers. But product prices are usually based on the open market. In the broiler industry, not only are most inputs provided by integrators, part or all of the market price and income risks are shifted from producers to integrators (Knoeber and Thurman, 1995). The latter is also true in the hog sector where production contracts are mainly between big producers who have production of their own and growers who do finishing (Rhodes, 1995). The last two forms are referred to generally as contract production.

But the degree of the contract provider's control over producers is much smaller in specialty grain than in livestock. This is related to differences in the production process. Structural changes in livestock industries are primarily driven by the technological advances that have standardized production processes and concentrated production space. By contrast, crop production is still more of an art and is more resistant to outside monitoring. Specialty grain contracts are a result of the lack of an open market for the specific qualities produced. Such diversity calls for close examination of the specificity in each sector.

Studies on specialty grain production have focused almost exclusively on producers-their risk and return (Kliebenstein and Hill, 1971), their characteristics and attitudes, etc. The other partner-either the processor or its agent-is rarely considered. The partnership of value creating and value-sharing is missing. For HOC and other proprietary value-enhanced grains, a niche market must be created as opposed to the traditional commodity grain market. The need to coordinate the players along the value chain calls for more than just contract production. In fact, contract production is only one element of this complex system. More importantly, we observe that close alignments are established between biotech firms

and seed firms, and alliances are formed between the technology provider and grain companies. There are several interesting questions to ask: what forces shape the relationships among all the partners? How are they determined optimally? How will they evolve over time? Is it market power or efficiency that is at work? Some researchers and policy makers are concerned that market power of large firms is squeezing small independent growers in this process, and some argue that efficiency might be the key. The answer will vary across different sectors where technology and degree of vertical coordination differ. A detailed study of this special case-DuPont's HOC will shed some light on the answer for the proprietary specialty grain sector.

This dissertation will attempt to answer the questions proposed above. Since much has been written about contract production per se, and since growers play a rather passive role in this value chain, our focus will be on the strategic partnership between Dupont, seed companies, grain companies, and Dupont's leading role in creating a market. In fact, what distinguishes the value-adding partnership of HOC and other proprietary value-enhanced gains is the participation and the leading role of the proprietary technology owner.

The approach employed in this paper is an incomplete contracting paradigm along the theory developed by Grossman & Hart (1986), Hart & Moore (1988) and others. We recognize that at least during the introductory stage of commercializing proprietary value-enhanced grains, incontractible relationship-specific private investments are significant and important, and therefore, play a significant role in shaping the construction of the participants' relationships. We will focus on the alliances between the technology provider and the grain companies, but will generalize the results to explain the other observed restructuring in the sector.

CHAPTER 4

THEORETICAL MODELS

4.1 Conjectures

When a new technology producing a new product is first introduced, uncertainty

regarding both the technology itself and the new product is high. Thus the value of the

technology is uncertain. The value will depend on the value of the product it produces. But it

takes time and effort for customers to learn about and accept a new product. Eight out of ten

new products introduced on the market fail every year. The cost of developing a new market

might discourage any outside party from undertaking the venture. Without demand, the

value of the technology is virtually zero. In order to realize and possibly increase the value

of this new technology, the innovator (Dupont for HOC) may have to participate in market-

creating efforts.

Another factor that could contribute to Dupont's involvement in the later stages of

value creation lies in the life cycle of the technology. During the introduction period, the

technology is immature and continued research effort on the part of Dupont is crucial to

popularize and enhance the production. Technical assistance from Dupont is essential to

growers, the yield performance of HOC has potential to be improved and more research and

development is needed. But this fact per se does not necessarily lead to the replacement of

arm's length market with contractual relationships, because conceptually these services

could be bought and sold in the form of a market transaction. It is the noncontractibility of

Dupont's effort that makes an arm's length relationship ineffective. That effort is subject to uncertainty and measurement difficulty, and therefore is not fungible. As a result, Continental or other grain companies will be reluctant to buy technical support or research from Dupont on the open market. On the other hand, Dupont will be reluctant to give up its technology at early stages, since more value can be expected with incremental investment in R&D. Besides, the strategic focus of Dupont, as a company, is shifting from the old-line chemical industry to the more promising life science sector.

We can also postulate that Dupont might buy out a grain company, but the lack of expertise in grain trade would possibly discourage that effort. It is difficult to manage two distinct lines of business, as has been demonstrated by many business failures blamed on shifting from the core business and losing focus. A contractual relationship that bypasses the grain companies between Dupont and domestic processors is feasible, but with overseas users, an efficient marketing and handling channel is a must. To preserve the autonomy of the grain company, an intermediate form, such as partial equity ownership, may be preferable to outright vertical integration.

Given that HOC can add value to end-users, and the economies of scale exist in marketing, the constraint in market development lies in growers' willingness to produce HOC. Positive externalities exist at the production level through learning-by-doing and at the marketing level through scale economies. But an individual grower would not take this into account when making a production decision. Following the infant industry argument, subsidies to growers in the forms of higher price premiums and lower seed prices at the early stage should be welfare improving for the system as a whole. The question is who will bear the cost of subsidy? Only the one who has the power to control the whole system and to

influence the value distribution has an incentive to do so. Here this party is Dupont, which owns the most indispensable factor in the production-technology. Being a big conglomerate, Dupont also has the financial ability to endure some losses in hope of getting larger return later.

As a technology matures and becomes more standardized, there will be less need for the technology provider to participate in downstream transactions unless it is of strategic significance. In view of the huge demand for feed corn, HOC, if it successfully overcomes its yield lags and volatility over time, may capture the whole feed corn market. If that is the case, the volume of its transactions will justify its being traded on the commodity market just like a separate grade of corn. However, identity preservation will remain an issue if it is more costly to produce HOC and/or if HOC commands a price premium over other corns. Contract production will remain as an option if testing costs are high enough. Otherwise, no contract production will be needed. More grain companies will enter the market and competition will prevail.

The industry structure in the grain industry has been constantly changing. Biotechnology is the force underlying the current restructuring. Crop seeds improved through biotechnology (including soybean, corn, cotton and potatoes) have been commercialized, and more genetically enhanced products are on the way. Those technologies are mostly developed and patented by private firms, and are by nature proprietary intellectual rights. Commercializing the new technologies, especially those involving value-added traits such as HOC, requires an innovative approach involving changes in relationships along the value chain. The implication for HOC is that we expect to see more coordination at the infancy stage of an industry and less in a mature one.

4.2 Grower's Acreage Decisions

Much research has been done on acreage response functions in agriculture.

Increasing evidences show that risk and/or risk behavior are important in agricultural

production decisions (Behrman, Just, Lin, Traill). Expected utility maximization is a useful

framework to approximate farmers' decisions under uncertainty[12]. Chavas and Holt (1990)

show that expected utility maximization could not be rejected for the U.S. corn and soybean

acreage decisions.

This paper will utilize the expected utility maximization approach to derive the

acreage response of HOC growers to price premiums. Since corn production acreage is

relatively stable year by year, the decision can be simplified as a representative grower

allocating resources between commodity corn and HOC for a given total corn acreage.

4.2.1 Setup

• Consider a grower who decides to allocate A acres of land to producing corn in the

coming season. Let $A1$ denote the number of acres devoted to commodity corn, and

$A2=A-A1$ acres devoted to HOC.

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[12] There are two approaches to represent an agent's preferences under uncertainty-the mean-standard deviation approach and the expected utility maximization approach. Meyer (1987) identifies a sufficient condition that makes these two approaches consistent and confirms that it holds in many economic models. The restriction is that the choice set is composed of random variables that differ from one another only by location and scale parameters, i.e., their cumulative distribution functions $G_1(.)$ and $G_2(.)$ have the property:

$G_1(x) = G_2(\alpha + \beta x)$ with $\beta > 0$. When this restriction is satisfied, expected utility maximization can be reduced to a two-moment decision model.

- p is the market price of commodity corn, which is assumed to be known at the beginning of the planting season to simplify the mathematics[13]. y is the yield per acre of commodity corn, which is a random variable with $E(y) = \bar{y}, Var(y) = \sigma_y^2$. c is the production cost per acre. Then random profit ($\pi 1$) from commodity corn is given by:

$$\pi 1 = (py - c)A1$$

- For HOC, consistent with our observation, the price is the market price of commodity corn (p) plus a premium (γ). Its yield per acre is ($y + \varepsilon$), where ε is a random variable independent of y with mean $\bar{\varepsilon}$ and variance σ_ε^2[14]. At the current stage, with HOC still in its introductory stage, $\bar{\varepsilon}$ is assumed to be negative to reflect possible yield drag and σ_ε^2 denotes the additional yield variability of HOC compared to that of commodity corn. We assume that the oil percentage of the HOC is not random and that the price premium is a fixed amount per bushel. In reality, the price premium schedule is a step function that depends on the stochastic oil content of the HOC. What is important here is that revenue from HOC is more variable than revenue from commodity corn and for simplicity in exposition, we choose to model the uncertainty in yield only. Cost per acre

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[13] We have implicitly assumed here and thereafter that the production of HOC won't affect the commodity corn price. The assumption here is appropriate when the total output of HOC is very small relative to the total output of commodity corn, as is the case in the early stages of HOC commercialization. We also assume the commodity corn price is known to focus on the difference between HOC and commodity corn. Farmers can hedge the price risk by using the well-developed future and options market, but the optimal hedge rule gives only a partial hedge due to yield uncertainty.

[14] We take this simple approach rather than the heteroschedastic approach with $y\varepsilon$ since there is no evidence for or against either of them and our main purpose to represent higher variability of HOC yield can be served by either of them. For the same reason, we assume y and ε are independent and there are no actual data supporting one way or the other.

is $(c + s)$ where s represents the seed premium of HOC over that of commodity corn[15];

s can take a negative value if there exists a seed subsidy. We adopt this structure to

reflect the fact that HOC and commodity corn production involves similar practices.

Random profit from HOC is given by $\pi 2$ and

$$\pi 2 = [(p + \gamma)(y + \varepsilon) - c - s]A2$$

- Profits are a random variable because yields are unknown at the time of decision

  making. However, in practice, γ is known before a production contract is signed.

  Moreover, given competition in the agricultural supply sector, input prices and thus costs

  per acre, i.e., s and c are known.

- A grower's initial wealth plus income from other operations is w.

  Assumption 1: A representative grower maximizes his expected utility.

  Then, the decision model is:

  $$\max_{A1,A2} E[u(w + \pi 1 + \pi 2)] s.t. A1 + A2 = A, A1 \geq 0, A2 \geq 0 \quad (1)$$

  In this general case, the signs of $\dfrac{\partial A2}{\partial \gamma}, \dfrac{\partial A2}{\partial s}$ are ambiguous.

4.2.2 A Model with CARA and Normality

Assumption 2: A representative grower has a CARA (constant absolute risk

aversion) utility function and normality can be assumed for the unknown variables[16].

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[15] There are likely other additional costs associated with producing HOC such as segregation cost during production and after harvest. We ignore these for the simplicity of analysis, but including them won't change the qualitative results of the analysis.

[16] Normality of random variable satisfies the restriction identified in Meyer (1987) that makes a two-moment decision model consistent with an expected utility maximization model. This assumption simplifies our analysis.

Under assumption 2, $E(u(w + \pi1 + \pi2) \propto E(w + \pi1 + \pi2) - \frac{1}{2}\lambda Var(w + \pi1 + \pi2)$[17]

where $\lambda > 0$ is the absolute risk aversion index. The bigger is λ, the more risk averse is the grower.

As long as nonsatiation is satisfied, the resource constraint $A1+A2=A$ will be binding and we can substitute $A-A2$ for $A1$. Therefore, under the additional CARA and normality assumptions, the grower's maximization problem becomes:

$$\max_{A2} E(w + \pi1 + \pi2) - \frac{1}{2}\lambda Var(w + \pi1 + \pi2) s.t. A2 \geq 0, A - A2 \geq 0 \quad (2)$$

With the setup in 4.2.1, we have

$$E(w + \pi1 + \pi2) - \frac{1}{2}\lambda Var(w + \pi1 + \pi2)$$

$$= w + pA\bar{y} - cA + \gamma A2\bar{y} + (p + \gamma)A2\bar{\varepsilon} - sA2 - \frac{\lambda}{2}\left[(pA + \gamma A2)^2\sigma_y^2 + (p + \gamma)^2 A2^2\sigma_\varepsilon^2\right]$$

For interior solutions $(A2)$, which is the case that we are interested in, the first order condition is

$$\gamma\bar{y} + (p + \gamma)\bar{\varepsilon} - s - \lambda(pA + \gamma A2)\gamma\sigma_y^2 - \lambda(p + \gamma)^2 A2\sigma_\varepsilon^2 = 0$$

Solving for $A2$, we obtain

$$A2 = \frac{(p + \gamma)\bar{\varepsilon} - s - \lambda pA\gamma\sigma_y^2 + \gamma\bar{y}}{\lambda\left[\gamma^2\sigma_y^2 + (p + \gamma)^2\sigma_\varepsilon^2\right]}$$

and $A2 \leq A$ (3)

$A2 = A$ *if* $A2 > A$

The second order sufficient condition is $-\lambda\gamma^2\sigma_y^2 - \lambda(p + \gamma)^2\sigma_\varepsilon^2 \leq 0$, which is always satisfied for $\lambda > 0$.

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[17] See Appendix 2 for details.

A couple of notes are in order:

- $\bar{\gamma}\bar{y} + (p+\gamma)\bar{\varepsilon} - s = E[(p+\gamma)(y+\varepsilon) - c - s - (py - c)]$ which is the expected gain per acre from growing HOC rather than commodity corn; and

$\gamma^2\sigma_y^2 + (p+\gamma)^2\sigma_\varepsilon^2 = E[(p+\gamma)(y+\varepsilon) - c - s - (py-c)]$ which is the increase in variability in profit from growing HOC compared to commodity corn. Therefore, A2 (the acreage allocated to HOC) is positively related to risk adjusted expected gain and negatively related to the associated increase in variability.

- A2=A when λ is small enough. Specifically, if $\lambda < \dfrac{(p+\gamma)\bar{\varepsilon} + \gamma\bar{y} - s}{A\left[p\gamma\sigma_y^2 + \gamma^2\sigma_y^2 + (p+\gamma)^2\sigma_\varepsilon^2\right]}$, which

is possible only when $(p+\gamma)\bar{\varepsilon} + \gamma\bar{y} - s > 0$ since $\lambda > 0$.

- A2>0 if $\lambda < \dfrac{(p+\gamma)\bar{\varepsilon} + \gamma\bar{y} - s}{p A \gamma\sigma_y^2}$, i.e., $\bar{y} + \bar{\varepsilon} + \dfrac{p\bar{\varepsilon} - s}{\gamma} > \lambda p A \sigma_y^2$ or $\gamma > \dfrac{s - p\bar{\varepsilon}}{\bar{y} + \bar{\varepsilon} - \lambda p A \sigma_y^2}$.

- A2=0 when λ is big enough for given (γ, s), i.e., when a grower is very risk averse, because HOC is riskier relative to commodity corn.

- A2<0 if $\gamma = 0$ and no HOC will be grown under our current assumptions of $\bar{\varepsilon} < 0$ and $\sigma_\varepsilon^2 > 0$.

- Examining (3) makes clear that the following results hold when A2>0, i.e., when HOC is grown, $\dfrac{\partial A2}{\partial \bar{y}} > 0, \dfrac{\partial A2}{\partial \bar{\varepsilon}} > 0, \dfrac{\partial A2}{\partial \lambda} < 0, \dfrac{\partial A2}{\partial p} < 0, \dfrac{\partial A2}{\partial \sigma_y^2} < 0, \dfrac{\partial A2}{\partial \sigma_\varepsilon^2} < 0, \dfrac{\partial A2}{\partial A} < 0, \dfrac{\partial A2}{\partial s} < 0$ [18], and

---

[18] Let $D = \lambda\left[\gamma^2\sigma_y^2 + (p+\gamma)^2\sigma_\varepsilon^2\right]$ and $N = (p+\gamma)\bar{\varepsilon} - s - \lambda p A \gamma\sigma_y^2 + \gamma\bar{y}$, then $D > 0$ and

$N > 0$ for $A2 > 0$ and $\lambda > 0$. $\dfrac{\partial A2}{\partial \bar{y}} = \dfrac{\gamma}{D} > 0$, $\dfrac{\partial A2}{\partial \lambda} = \dfrac{-pA\gamma\sigma_y^2 D - N\dfrac{D}{\lambda}}{D^2} < 0$ etc..

for commodity corn, when $A1 > 0$,

$$\frac{\partial A1}{\partial y} < 0, \frac{\partial A1}{\partial \varepsilon} < 0, \frac{\partial A1}{\partial \lambda} > 0, \frac{\partial A1}{\partial p} > 0, \frac{\partial A1}{\partial \sigma_y^2} > 0, \frac{\partial A1}{\partial \sigma_\varepsilon^2} > 0, \frac{\partial A1}{\partial A} > 0, \frac{\partial A1}{\partial s} > 0 \text{ because}$$

$$A1 = A - A2.$$

- The sign of $\dfrac{\partial A2}{\partial \gamma}$ is not obvious without more assumptions (see Appendix 2).

4.2.3 Properties of Acreage Decisions under CARA Utility Maximization

The empirical implications of the expected CARA utility maximization are summarized as the following[19].

- First, given that HOC has higher yield variability, the less risk averse growers are more likely to adopt the new product. For those who choose to produce some HOC, the acreage allocated to HOC increases as a grower becomes less risk averse

$$\left(\frac{\partial A2}{\partial \lambda} < 0 \text{ if } A2 > 0 \right).$$

- Second, if the expected yield of HOC is less than that of commodity corn, then no cash growers will grow it without a guaranteed positive price premium above the market price[20]. For a given risk attitude, a certain price premium is necessary to entice the grower to plant some HOC. This minimum price premium increases with the degree of risk aversion.

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[19] CARA implies a zero wealth effect, which is probably reasonable given the similarity in returns for HOC and commodity corn.

[20] There may be a greater implicit price premium for livestock producers compared with cash growers who must share the added value with others in the value chain.

- Third, the acreage devoted to HOC increases with $\bar{\varepsilon}$ and decreases with σ_ε^2 and σ_y^2

$$\left(\frac{\partial A2}{\partial \bar{\varepsilon}} > 0, \frac{\partial A2}{\partial \sigma_y^2} < 0, \frac{\partial A2}{\partial \sigma_\varepsilon^2} < 0 \right).$$ The higher its yield and the smaller its variability, the

more attractive is HOC.

- Fourth, a higher $\bar{y}$, a lower p, or a lower A induces a higher acreage of HOC

$$\left(\frac{\partial A2}{\partial \bar{y}} > 0, \frac{\partial A2}{\partial p} < 0, \frac{\partial A2}{\partial A} < 0 \right).$$ This is because $\bar{y}$ magnifies the positive effect of γ, which

is conducive to HOC; p magnifies the negative effect of the yield drag, and A

magnifies the negative effect of γ - increasing the variability of household's income,

which is not favorable to HOC, certis paribus. Holding other things constant, a higher

$\bar{y}$ means a higher premium is paid for each acre of land, and higher p means the

premium has less weight.

- Fifth, acreage of HOC decreases with s since s represents higher production cost

$$\left(\frac{\partial A2}{\partial s} < 0 \right).$$

- Finally, the effect of γ on $A2$ is ambiguous due to its the two-folded impacts on the

desirability of HOC. It increases the income of grower but at the cost of increasing its

variability. The balance of these two effects should give us the optimal value of γ.

Nevertheless, under quite general conditions, $A2$ will increase with γ as long as HOC is

planted at all. In that range of parameters, the positive effect of γ outweighs the negative

one.

In general, the total volume of HOC produced is

$$Y = A2(\gamma, s, \bar{\varepsilon}, \sigma_\varepsilon^2)(y + \varepsilon) = Y(\gamma, s, \bar{\varepsilon}, \sigma_\varepsilon^2).$$

Assumption 3: Aggregate behavior can be represented by a representative grower

making decisions according to (2).

The total HOC output (Y) then can be specified given what we have derived above,

i.e., $Y = A2(\gamma, s, \bar{\varepsilon}, \sigma_\varepsilon^2)(y + \varepsilon) = Y(\gamma, s, \bar{\varepsilon}, \sigma_\varepsilon^2)$ with $\dfrac{\partial Y}{\partial s} < 0, \dfrac{\partial Y}{\partial \bar{\varepsilon}} > 0, \dfrac{\partial Y}{\partial \sigma_\varepsilon^2} < 0$. And $\dfrac{\partial Y}{\partial \gamma} > 0$ if

$\dfrac{\partial A2}{\partial \gamma} > 0$ which holds under certain conditions (See Appendix 2).

Assumption 4: The conditions hold such that $\dfrac{\partial Y}{\partial \gamma} > 0$ for the rest of analysis, which

is consistent with empirical evidence.

A price premium in terms of a fixed amount per bushel above the market price as we

use here is used for HOC and almost all the other specialty grain, although a price premium

in terms of percentage increase of market price could be an option too. However, if the latter

is used, the results won't change.

4.3 Determination of the Price Premium for HOC

4.3.1 Value to End-users

4.3.1.1 Experimental Data

HOC is targeted at the animal feed industry in which corn is a major ingredient.

Many studies have been done to determine its value for end-users. According to Optimum's

website viewed in May 1998, one of these studies is based on Midwest swine trials between

Jan. 1994 and Dec. 1996. In the experiment, two diets (Optimum HOC/ typical corn) which

were formulated to be iso-caloric, were fed to separated groups of hogs. Ingredient and hog

prices were based on a 10-year average, with corn valued at $2.50/bu. Optimum HOC was

calculated to be worth an additional $0.48 per bushel[21]. Another study conducted by DuPont

sponsored researchers shows that HOC can effectively be used as a superior substitute for

typical corn in feedlot rations. A diet in which HOC was substituted for typical corn on a

weight basis in a diet that was previously optimized for typical corn produced a 4.5%

increase in maintenance and gain energy.

4.3.1.2 Two Measurements

The experiments mentioned above give two measurements of the value of HOC

relative to typical corn. One is to formulate the diet with HOC to have the same energy level

of an optimized typical corn diet. The difference in diet cost then is the added value of HOC.

Alternatively, one can compare the costs of optimized diets that produce the same weight

gain in animals. The second method is to substitute HOC for typical corn in an optimal

typical corn diet on a weight basis. The extra gain of the animal then is attributed to HOC.

A characteristics approach: Measurement 1 bases the value of HOC on its close

substitutes such as typical corn and fat, and it is essentially determined by their prices. This

is in the spirit of characteristic approach to consumer theory. "...goods possess, or give rise

to, multiple characteristics in fixed proportions and that it is these characteristics, not goods

themselves, on which the consumer's preferences are exercised." (Lancaster, Kelvin J.) In

the case of animal feed, it is the elements in the ingredients such as oil, starch and protein,

that contribute energy to the productivity of animals. Thus those elements can be valued.

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[21] The calculated added value depends greatly on the choices of the prices of the substitutes, which tend to vary greatly over time.

The value of an ingredient, composed of fixed proportions of multiple characteristics, should be the sum of the values of its characteristics.

A value of marginal product approach: Measurement 2 bases the value of HOC on its marginal product, and thus on the price of the end product it is used to produce. The problem in this approach is that the ration with HOC is not optimized. More value can be realized if rations are optimized because animal performance depends significantly on rations. The value obtained this way therefore serves as a lower bound on the value of HOC. Since measurement 1 is based on optimized rations, the value obtained there is an upper bound of the value of HOC. The average value of HOC in actual use might be somewhere in between these two, due to different practices of animal feeders.

Another complication in deriving the value of HOC is that optimal rations for different animals are different, and there is also a life cycle effect which may divide the animal life into 4-8 phases when different nutritional needs exist. This factor could potentially lead to different results for the experiments carried out by Dupont researchers. Measurement 2 is also subject to this limitation when values of marginal products are not equalized for an input across different uses.

Theoretically, competition and free entry and free exit in all industries should drive the value of marginal product of an input to be equal across all uses, and value of the input to be equal to the value of its marginal product. Such is also true for a characteristic used as an input, which means that measurements 1 and 2 would give the same results under some ideal conditions.

A characteristic approach is preferred to measure the value of HOC. The animal ingredients market is fairly competitive. Feeders optimize rations under the guidance of

nutritionists to minimize their cost per unit gain. It is easier and more reasonable to evaluate HOC on the basis of its characteristics relative to those of its close substitutes readily available on the market.

Using data on typical corn, fat and other animal feed ingredients, a hedonic model can be used to estimate the prices of HOC's key elements- oil, starch and protein. The added value of HOC relative to typical commodity corn can be calculated similarly. This value is not fixed over time; it varies with the prices of commodity corn and other substitutes, which vary with changing market conditions. In particular, as the percentage of HOC in the feed market rises, the total supply of HOC corn will affect the prices of commodity corn and the price of fat. In such a situation, one cannot regard $\overline{\beta}$ as fixed.

4.3.2 The Price Premium Charged to Processors/End-users

Consider the price premium that can be charged to the end users: Let $\overline{\beta}$ be the added value of HOC, which is competitively determined by the prices of its substitutes. $\overline{\beta}$ could be estimated using a hedonic model as suggested above. However, the price premium denoted as β that the grain marketer can charge its customers will depend on the HOC market itself- the number and relative sizes of customers. In a perfectly competitive world, without complications like relationship-specific investments, β will be the same as the added value of HOC ($\overline{\beta}$) obtained above, assuming the grain marketer has all the bargaining power. When customers are large, β will depend on the relative bargaining power of the parties involved. When customers are small, the grain marketer will have all the bargaining power, and can maximize its gain subject to the participation constraints of its customers.

4.3.2.1 A Special Case-the Grain Marketer Has All the Bargaining Power

Assume in this section that all HOC for export is marketed through Continental, as was the case during the period 1996-1998. Continental's overseas customers were spread over Asian and Latin American, and are small relative to Continental. Each customer's purchasing volume is small relative to the total marketed volume (Y), and total marketing cost does not change significantly for different combinations of customers. The HOC business is constrained primarily at the production stage, and demand will be perfectly elastic for HOC at the price with appropriate marketing effort. Given these conditions, Continental has all the bargaining power, and it maximizes the price premium it charges (β) subject to the participation constraint of processors.

The setup is given as the following:

- Let p^p be processors' selling price of processed commodity corn. They can charge a price premium equal to its added value $\overline{\beta}$ for processed HOC. p^p is competitively determined.

- Commodity corn and HOC are essential inputs (denoted as x). A processor's output (y) is normally proportional to x. We will ignore weight loss in processing and then $y = x$.

- A processor pays price p per unit to obtain the quantity of commodity corn x, and p is competitively determined by market. Let f_c be the fixed cost associated with processing commodity corn and $VC_c(x)$ be the variable cost of processing amount x of commodity corn. Then, with commodity corn, a processor's profit is

$\pi_c^p (\overline{\beta} = 0, \beta = 0, f_c) = \max_x p^p x - px - f_c - VC_c(x)$ where the subscript c denotes

commodity corn.

- With HOC, a processor pays a price of $(p + \beta)$ for each unit, and charges a premium of

  $\overline{\beta}$ in addition to p^p for each unit of processed HOC. Let f_h be the fixed cost and

  $VC_h(x)$, the variable cost of processing HOC. Then, the processor's profit is

  $\pi_H^p (\overline{\beta}, \beta, f_H) = \max_x (p^p + \overline{\beta})x - (p + \beta)x - f_H - VC_H(x)$ where the subscript

  H denotes HOC.

For each processor who purchases the product from Continental, Continental solves the following problem:

$$\max_\beta \beta \quad \text{s.t} \quad \pi_H^p \geq \pi_c^p$$

The idea is for Continental to charge as large of a premium as is possible subject to

the constraint that a processor chooses to buy HOC. Solving the problem will give the price

premium β^*, and it is determined by $\pi_H^p (\overline{\beta}, \beta^*, f_H) = \pi_c^p (0,0, f_c)$. The processor will be

just indifferent between using HOC and commodity corn, and Continental obtains the

maximum premium for HOC.

From $\pi_H^p(\overline{\beta}, \beta^*, f_H) = \pi_c^p(0,0, f_c)$, we obtain

$\pi_H^p(\overline{\beta}, \beta^*, f_H) - \pi_c^p(0,0, f_c) = 0$ which gives the comparative statics results:

$$\frac{\partial \beta^*}{\partial \overline{\beta}} = -\frac{\frac{\partial \pi_H^p(\overline{\beta}, \beta^*, f_H)}{\partial \overline{\beta}}}{\frac{\partial \pi_H^p(\overline{\beta}, \beta^*, f_H)}{\partial \beta^*}} > 0 \text{ and } \frac{\partial \beta^*}{\partial f_H} = -\frac{\frac{\partial \pi_H^p(\overline{\beta}, \beta^*, f_H)}{\partial f_H}}{\frac{\partial \pi_H^p(\overline{\beta}, \beta^*, f_H)}{\partial \beta^*}} < 0^{22}.$$

β^* increases with $\overline{\beta}$ and decreases with f_H. The more valuable HOC is to end-

users, the higher premium Continental can charge its customers. Higher costs to process

HOC reduces the premium that a processor is willing to pay. In fact, when the cost of

processing HOC is high enough, the added value of HOC will not be able to cover those

costs, and HOC will not be used at all.

We expect $\overline{\beta}$ to vary across customers and countries and so the optimal β^* will

typically vary accordingly as well. We take the average of β^* for the analysis in the next

section.

4.4 Analysis of the Strategic Partnership between Dupont and Continental Grain

In early 1996 when the commercialization of HOC was in its infancy, Dupont

teamed up with Continental Grain to market HOC overseas. The essential factors in

realizing the value of HOC are the technology and identity-preserved marketing. Dupont is

the owner of the technological innovation and Continental is one of the biggest global grain-

marketing firms. The success of HOC calls for the combination of the technology of Dupont

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[22] They are independent of $\pi_c^p(0,0, f_c)$ since $\pi_c^p(0,0, f_c)$ is not dependent on $\beta^*, \overline{\beta}$ and f_H.

and the marketing expertise of Continental. The bottleneck is that the small volume of HOC

produced makes marketing through the conventional marketing channel very expensive.

Lack of an assured marketing channel and a guaranteed price premium will limit or even

prevent cash growers from producing HOC. Thus a grain firm is indispensable. Indeed,

before Dupont formed alliances with Continental, its experiences with HOC were

unsuccessful, since producers were faced with significantly lower yields and an inadequate

market structure to effectively handle the crop (Jones, 1998).

4.4.1 A Model without Private Investment

Cooperation between these two firms should produce more benefit for them than an

arm's length market relationship. One possible source of gain is that if they share the total

surplus from HOC marketing, then DuPont can capture some of the return from marketing

HOC, which provides DuPont with more incentive to create a market for HOC.

As shown in Section 4.2, two variables that are potentially controllable, the seed premium

that a grower is charged (s) and the price premium that a grower receives (γ), affect his

acreage decisions.

Pioneer and Monsanto control almost half of the total corn seed market in Northern

America. Since Monsanto didn't license HOC technology from DuPont, Pioneer is the

market leader in the HOC seed business with other firms supplying HOC seeds being small,

therefore, it can effectively set the price premium for HOC seeds subject to competition

from other corn seed varieties. With its equity stake in Pioneer, Dupont can actually control

the price premium for HOC seeds (s) directly through Pioneer, and it will get a fee $r(s)$ for

every acre of HOC planted, we call this fee, a license fee in general. This license fee will be

positively related to the seed premium, i.e., $\left(\dfrac{\partial r(s)}{\partial s} > 0 \right)$ and in fact may be equal to it in

which case $\dfrac{\partial r(s)}{\partial s} = 1$. If a grain companies market HOC independently, the price premium

for HOC given to the growers (γ) will be determined solely by the grain company.

The seed premium (s) affects not only the licensing income, but also the gain in the

marketing stage since the current constraint is mainly that not enough volume is produced

and economies of scale can not be achieved in the marketing channel and total HOC

production decreases with increasing $s\left(\dfrac{\partial Y}{\partial s} < 0 \right)$. If Dupont can't get part of the surplus

from marketing HOC, it will ignore the impact of s on the gain in the marketing stage. At

the beginning stage, when there is relationship specific cost such as dedicated assets

associated with the project, a grain firm without a say on the seed price might find itself

vulnerable in the market. Similarly, the price premium (γ) will affect not only the gain in

the marketing stage, but the licensing income as well because that the growers' acreage

decisions are dependent on γ $\left(\dfrac{\partial Y}{\partial \gamma} > 0 \right)$. If γ is determined independently by the grain

company, it will not take the second impact into consideration. From a game theoretic point

of view, γ and s affect not only the distribution of the available surplus to relevant agents,

but also the size of joint surplus. In fact, the cooperatively determined γ and s will

maximize the joint surplus, generating a bigger pie than the noncooperatively determined

variables. Total surplus will be divided through bargaining. In particular, we would expect

higher γ and lower s under cooperation, which can be illustrated by the following model.

Proposition 1: Price premiums paid to growers are higher and seed premiums charged are lower when they are jointly determined to maximize the joint surplus than otherwise.

- Assume for a given technology, HOC is sold to processors/end-users at a premium of β per bushel above the commodity price p. As stated before, β is the average of β^* s that are determined in section 4.3.2; therefore, it is not a choice variable in this stage of decision-making. The commodity corn price p is competitively determined and thus given as well[23].

- Let the total seed license fee be $r = r(s)A2(\gamma,s)$ with $\dfrac{\partial r(s)}{\partial s} > 0$ where s is the seed premium that a seed firm charges for HOC seeds.

- To market HOC, some fixed relationship-specific cost F has to be incurred.

- The total amount of HOC produced is $Y = A2(\gamma,s)(y + \varepsilon)$ with $E(y) = \bar{y}$ and $E(\varepsilon) = \bar{\varepsilon}$ (see section 4.2 for more detailed definitions).

- The variable marketing cost of moving grain of amount Y from Continental to the processors/end-users is $VC(Y)$ with $\dfrac{\partial VC(Y)}{\partial Y} > 0$ and $\dfrac{\partial^2 VC(Y)}{\partial Y^2} < 0$.

- Dupont and Continental, being large conglomerates, are assumed to be risk neutral.

The joint profit or the total surplus to the alliance between DuPont and Continental is given by (TS)[24]:

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[23] See footnote 12 on P. 32. If the total output of HOC were large enough, the price of HOC and commodity corn would be determined endogenously as two competing differentiated products.

[24] The setup of total surplus in this form is dependent on the fact that there is not enough production of HOC at this stage to affect the price of commodity corn.

$$TS = E[r(s)A2(\gamma, s) + (p + \beta)Y - (p + \gamma)Y - F - VC(Y)]$$
$$= E[r(s)A2(\gamma, s) + (\beta - \gamma)A2(\gamma, s)(y + \varepsilon) - F - VC(A2(\gamma, s)(y + \varepsilon))]$$
$$= r(s)A2(\gamma, s) + (\beta - \gamma)A2(\gamma, s)(\overline{y} + \overline{\varepsilon}) - F - E[VC(A2(\gamma, s)(y + \varepsilon))]$$

Under cooperation, Dupont and Continental will choose γ and s to maximize

expected total surplus (TS), i.e.,

$$\max_{\gamma, s} TS$$
$$= \max_{\gamma, s} r(s)A2(\gamma, s) + (\beta - \gamma)A2(\gamma, s)(\overline{y} + \overline{\varepsilon}) - F - E[VC(A2(\gamma, s)(y + \varepsilon))] \quad (4)$$

Joint surplus is thus made of license fees $[(r(s)A2(\gamma, s)]$ and price premiums

obtained from HOC users minus premiums paid to growers $[(\beta - \gamma)A2(\gamma, s)(\overline{y} + \overline{\varepsilon})]$ minus

the fixed and variable costs of marketing the HOC.

Assume the second order sufficient conditions are satisfied. For interior solutions,

the first order conditions are:

$$\gamma : [r(s) + (\beta - \gamma)(\overline{y} + \overline{\varepsilon})]\frac{\partial A2}{\partial \gamma} - A2(\gamma, s)(\overline{y} + \overline{\varepsilon}) - E\left[\frac{\partial VC}{\partial Y}\frac{\partial A2}{\partial \gamma}(y + \varepsilon)\right] = 0$$
$$s : [r(s) + (\beta - \gamma)(\overline{y} + \overline{\varepsilon})]\frac{\partial A2}{\partial s} + A2(\gamma, s)\frac{\partial r(s)}{\partial s} - E\left[\frac{\partial VC}{\partial Y}\frac{\partial A2}{\partial s}(y + \varepsilon)\right] = 0$$

$$(5)^{25}$$

Denote the solutions to (5) as (γ^*, s^*).

These first order conditions are merely that the marginal benefit is equal to the

marginal cost of changing the choice variables. Rearrange (5) and we will have:

$$\gamma : [r(s) + (\beta - \gamma)(\overline{y} + \overline{\varepsilon})]\frac{\partial A2}{\partial \gamma} = A2(\gamma, s)(\overline{y} + \overline{\varepsilon}) + E\left[\frac{\partial VC}{\partial Y}\frac{\partial A2}{\partial \gamma}(y + \varepsilon)\right] \quad (5\text{-A})$$

---

[25] We can take $\dfrac{\partial A2}{\partial \gamma}, \dfrac{\partial A2}{\partial s}$ out of the expectation function because $A2$ is independent of variables y and ε.

$$s : A2(\gamma,s)\frac{\partial r(s)}{\partial s} - E\left[\frac{\partial VC}{\partial Y}\frac{\partial A2}{\partial s}(y+\varepsilon)\right] = -\left[r(s)+(\beta-\gamma)(\overline{y}+\overline{\varepsilon})\right]\frac{\partial A2}{\partial s} \quad (5\text{-}B)$$

The left side of (5-A) is the increase of the license fee and the gain from marketing

HOC; the right side is the marginal cost associated with the change of γ: the first term is the

increase in premium paid to growers, and the second term is the increase in marketing cost.

Similarly, on the left side of (5-B), the first term is the increase of the license fee due to

higher seed premium s, and the second term is the reduction in marketing cost due to the

smaller volume induced by higher seed premium. On the left side is the loss arising from the

lost seed license fee and the lost gain from marketing HOC due to less acreage allocated to

produce HOC.

Without cooperation, Continental will choose γ to maximize its profit from selling

HOC and Dupont chooses s to maximize its license fee. Their decisions are respectively,

Continental: $\max_{\gamma} E[(\beta-\gamma)Y - F - VC(Y)]$ (6-C)

DuPont: $\max_{s} r(s)A2(\gamma,s)$ (6-D)

Assume that the second order sufficient conditions for both (6-C) and (6-D) are

satisfied. For interior solutions, their first order conditions are respectively,

$$\gamma : \left[(\beta-\gamma)(\overline{y}+\overline{\varepsilon})\right]\frac{\partial A2}{\partial \gamma} - A2(\gamma,s)(\overline{y}+\overline{\varepsilon}) - E\left[\frac{\partial VC}{\partial Y}\frac{\partial A2}{\partial \gamma}(y+\varepsilon)\right] = 0 \quad (7\text{-}C)$$

$$s : r(s)\frac{\partial A2}{\partial s} + A2(\gamma,s)\frac{\partial r(s)}{\partial s} = 0 \quad\quad (7\text{-}D)$$

Solve (7-C) and (7-D) jointly, and denote the solutions as $(\tilde{\gamma}, \tilde{s})$.

To compare (γ^*, s^*) with $(\bar{\gamma}, \bar{s})$, we evaluate (5) at $(\bar{\gamma}, \bar{s})$ using the first order

conditions of (7-C) and (7-D). By doing so we obtain,

$$\gamma : \left[r(\bar{s}) + (\beta - \gamma)(\bar{y} + \bar{\varepsilon}) \right] \frac{\partial A2}{\partial \gamma} - A2(\bar{\gamma}, \bar{s})(\bar{y} + \bar{\varepsilon}) - E\left[\frac{\partial VC}{\partial Y} \frac{\partial A2}{\partial \gamma}(y + \varepsilon) \right]$$

$$= r(\bar{s}) \frac{\partial A2}{\partial \gamma} + \left\{ (\beta - \gamma)(\bar{y} + \bar{\varepsilon}) \frac{\partial A2}{\partial \gamma} - A2(\bar{\gamma}, \bar{s})(\bar{y} + \bar{\varepsilon}) - E\left[\frac{\partial VC}{\partial Y} \frac{\partial A2}{\partial \gamma}(y + \varepsilon) \right] \right\} \ (8\text{-A})^{26}$$

$$= r(\bar{s}) \frac{\partial A2}{\partial \gamma} > 0$$

$$s : \left[r(\bar{s}) + (\beta - \gamma)(\bar{y} + \bar{\varepsilon}) \right] \frac{\partial A2}{\partial s} + A2(\bar{\gamma}, \bar{s}) \frac{\partial r(s)}{\partial s} - E\left[\frac{\partial VC}{\partial Y} \frac{\partial A2}{\partial s}(y + \varepsilon) \right]$$

$$= \left[(\beta - \gamma)(\bar{y} + \bar{\varepsilon}) - E\left[\frac{\partial VC}{\partial Y}(y + \varepsilon) \right] \right] \frac{\partial A2}{\partial s} < 0$$

$$(8\text{-B})^{27}$$

To simplify notations, let

$$\theta = TS(\gamma, s) = E\left[r(s)A2(\gamma, s) + (p + \beta)Y - (p + \gamma)Y - F - VC(Y) \right], \text{ then (5) becomes:}$$

---

^{26} (8-A) holds since $\left\{ (\beta - \gamma)(\bar{y} + \bar{\varepsilon}) \frac{\partial A2}{\partial \gamma} - A2(\bar{\gamma}, \bar{s})(\bar{y} + \bar{\varepsilon}) - E\left[\frac{\partial VC}{\partial Y} \frac{\partial A2}{\partial \gamma}(y + \varepsilon) \right] \right\} = 0$ according

to (7-C), and $\frac{\partial A2}{\partial \gamma} > 0$.

^{27} From (7-D) we have at $(\bar{\gamma}, \bar{s})$, $r(\bar{s}) \frac{\partial A2}{\partial s} + A2(\bar{\gamma}, \bar{s}) \frac{\partial r(\bar{s})}{\partial s} = 0$. From (7-C) we get,

$$\left[(\beta - \gamma)(\bar{y} + \bar{\varepsilon}) \right] \frac{\partial A2}{\partial \gamma} - A2(\bar{\gamma}, \bar{s})(\bar{y} + \bar{\varepsilon}) - E\left[\frac{\partial VC}{\partial Y} \frac{\partial A2}{\partial \gamma}(y + \varepsilon) \right] = 0$$

Rearrange the terms and we will get at $(\bar{\gamma}, \bar{s})$,

$$\left[(\beta - \gamma)(\bar{y} + \bar{\varepsilon}) - E\left[\frac{\partial VC}{\partial Y}(y + \varepsilon) \right] \right] \frac{\partial A2}{\partial \gamma} = A2(\bar{\gamma}, \bar{s})(\bar{y} + \bar{\varepsilon}) > 0$$

and since $\frac{\partial A2}{\partial \gamma} > 0$, we will have $\left[(\beta - \gamma)(\bar{y} + \bar{\varepsilon}) - E\left[\frac{\partial VC}{\partial Y}(y + \varepsilon) \right] \right] > 0$. This result, together

with $\frac{\partial A2}{\partial s} < 0$ and (7-D), will make (8-B) hold.

$$\gamma : \theta_\gamma(\gamma, s) = 0$$
$$s : \theta_s(\gamma, s) = 0 \qquad (5')$$

The second order condition is: $H = \begin{vmatrix} \theta_{\gamma\gamma} & \theta_{\gamma s} \\ \theta_{s\gamma} & \theta_{ss} \end{vmatrix}$ is negative definite, which gives:

$$\theta_{\gamma\gamma} < 0, \ \theta_{ss} < 0, \ \theta_{\gamma\gamma}\theta_{ss} - \theta_{\gamma s}\theta_{s\gamma} > 0 \Rightarrow \left| \frac{\theta_{ss}}{\theta_{s\gamma}} \right| > \left| \frac{\theta_{\gamma s}}{\theta_{\gamma\gamma}} \right|.$$

Using (5') and the Implicit Function Theorem, we obtain,

$$\left. \frac{d\gamma}{ds} \right|_{\theta_s = 0} = -\frac{\theta_{ss}}{\theta_{s\gamma}}, \ \left. \frac{d\gamma}{ds} \right|_{\theta_\gamma = 0} = -\frac{\theta_{\gamma s}}{\theta_{\gamma\gamma}}.$$

(8-A) and (8-B) give $\theta_\gamma \big|_{(\bar{\gamma}, \bar{s})} > 0$ and $\theta_s \big|_{(\bar{\gamma}, \bar{s})} < 0$.

If $\theta_{\gamma s} < 0$ (see Appendix 2-C for the sign of $\theta_{\gamma s}$), then $\left. \dfrac{d\gamma}{ds} \right|_{\theta_s = 0} = -\dfrac{\theta_{ss}}{\theta_{s\gamma}} < 0$ because

$\theta_{ss} < 0$ by the second order conditions. Similarly, $\left. \dfrac{d\gamma}{ds} \right|_{\theta_\gamma = 0} = -\dfrac{\theta_{\gamma s}}{\theta_{\gamma\gamma}} < 0$ because

$\theta_{\gamma\gamma} < 0$. Given these negative slopes, we can draw the graph in Figure 3-A.

In Figure 3-A, the segment AB gives us the combination of (γ, s) that satisfies the

first order condition for s: $\theta_s(\gamma, s) = 0$. The area to the right of AB gives (γ, s) such that

$\theta_s(\gamma, s) < 0$ since $\theta_{ss} < 0$, and for those (γ, s) that lie below AB, $\theta_s(\gamma, s) > 0$. Similarly,

segment CD gives (γ, s) such that the first order condition $\gamma : \theta_\gamma(\gamma, s) = 0$ is satisfied; for

those above CD, $\theta_\gamma(\gamma, s) < 0$; and for those lying below CD, $\theta_\gamma(\gamma, s) > 0$. Therefore, we

have $\bar{\gamma} < \gamma^*, \bar{s} > s^*$ and Proposition 1 is proved for the case with $\theta_{\gamma s} < 0$. For the case when

$\theta_{\gamma s} > 0$, which is more likely, we have the graph in Figure 3-B.
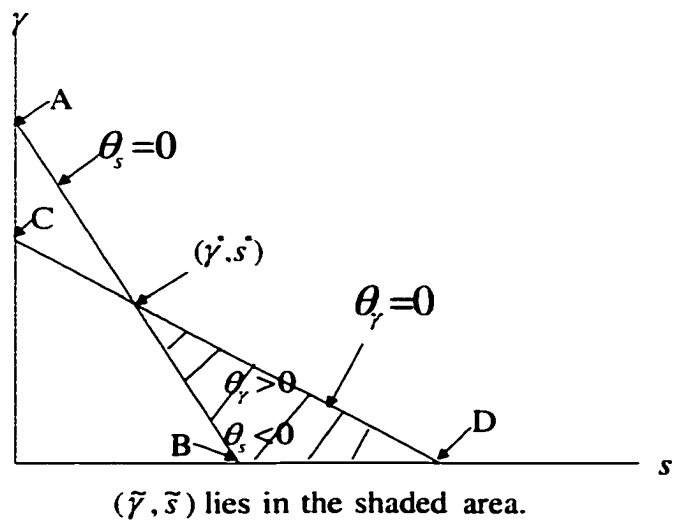
Figure 3-A: A Graphic Proof of the Result in 4.4.1 ($\theta_{ys} < 0$)
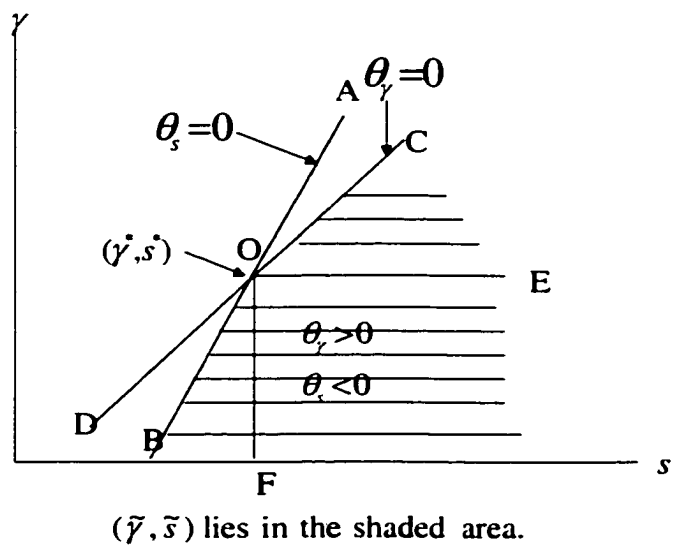
Figure 3-B: A Graphic Proof of the Result in 4.4.1 ($\theta_{ys} > 0$)

As before, in Figure 3-B, the segment AB gives us the combination of (γ, s) that

satisfies the first order condition for s: $\theta_s(\gamma, s) = 0$. The area to the left of AB gives

(γ, s) such that $\theta_s(\gamma, s) > 0$ since $\theta_{ss} < 0$; and for those (γ, s) that lie to the right of AB,

$\theta_s(\gamma, s) < 0$. Similarly, segment CD gives (γ, s) such that the first order condition

γ: $\theta_\gamma(\gamma, s) = 0$ is satisfied. For those (γ, s) that lie to the right of CD, $\theta_\gamma(\gamma, s) > 0$, and for

those to the left of CD, $\theta_\gamma(\gamma, s) < 0$. Therefore, $(\tilde{\gamma}, \tilde{s})$ lies in the shaded area in Figure 3-B

when $\theta_{\gamma s} > 0$. This gives $(\tilde{\gamma} < \gamma^*$ and $\tilde{s} > s^*)$ in area EOF, $(\tilde{\gamma} < \gamma^*$ and $\tilde{s} < s^*)$ in area BOF,

and $(\tilde{\gamma} > \gamma^*$ and $\tilde{s} > s^*)$ in area AOC. Only when (γ, s) lies in area EOF, will Proposition 1

hold.

By the definition of maximization, total surplus

$(TS = E[r(s)A2(\gamma, s) + (p + \beta)Y - (p + \gamma)Y - F - VC(Y)])$ is higher with (γ^*, s^*) than

with $(\tilde{\gamma}, \tilde{s})$, which means that cooperation is preferable to pure open market transactions.

This is similar to the result obtained from standard oligopoly models. The intuition is that

when the decisions are carried out independently, neither party will take into account of the

negative impact on the other party's profitability of its action. When the decisions are made

cooperatively, the externalities are internalized.

As long as γ and s are contractible, which is reasonable in the case of HOC,

cooperation can be achieved by contracting.

4.4.2 A Model with Private Investments

The private investment incentive is a second factor that can lead to gains in

cooperation between Dupont and Continental. The previous model takes technology as

given, but it is more likely that continued research to improve HOC's performance and technical assistance to growers from Dupont will be important at the initial stage. These factors will most possibly influence Y - the volume of HOC produced. Continental's private action affects marketing costs to a large degree. All theOse private investments are not contractible, because it would be very costly, if not impossible, for them to be verified by a third party due to uncertainty and unmeasurability of private efforts.

Proposition 2: When private investments are not contractible, at least one firm and most possibly both firms will underinvest.

- Denote Dupont's effort at R&D as i. Higher i will lead to higher Y. The cost of this effort to Dupont is $c(i)$, and $c(0) = 0, c'(i) > 0, c''(i) > 0 \; \forall i, c'(i = 0) >> 0$.

- Denote Continental's actions to make marketing efficient as I. Action I reduces $VC(Y)$ at a cost of $C(I)$ to Continental. Assume $C(0) = 0, C'(I) > 0, C''(I) > 0 \; \forall i, C'(I = 0) >> 0$.

- To simplify notation, write the license (or royalty) fee as $r(s, Y)$ as opposed to $r = r(s)A2(\gamma, s)$ used in section 4.4.1 .

Total surplus of the project now is,

$$
\begin{aligned}
TS &= r(s,Y) + (p + \beta)Y(i,\gamma,s) - (p + \gamma)Y(i,\gamma,s) - F - VC(Y,I) - c(i) - C(I) \\
&= r(s,Y) + (\beta - \gamma)Y(i,\gamma,s) - F - VC(Y,I) - c(i) - C(I) \qquad (9) \\
&= B(i,I,\gamma,s) - F - c(i) - C(I)
\end{aligned}
$$

where $r(s,Y) + (\beta - \gamma)Y(i,\gamma,s) - VC(Y,I) = B(i,I,\gamma,s)$

p, the commodity price, is competitively given; β is determined in a previous stage as shown in section 4.2.2. Therefore, the choice variables here are (i, I, γ, s). The decisions are carried out in four stages. First, the two parties choose private actions (i, I); second,

they negotiate on the values of (γ, s). After that, production contracts are signed with

growers and total surplus is realized. Finally, they bargain over the gain given their outside

options (see Figure 4).

1	2	3	4
Choose i I separately	Negotiate on (γ, S)	Contract with growers and processors and realize the total surplus	Bargain over the gain over outside options

time
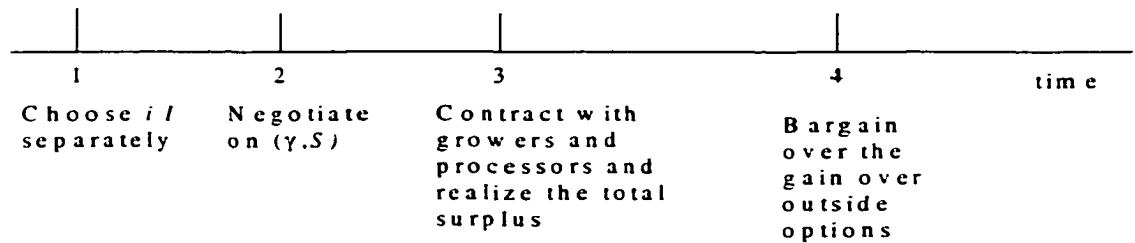
Figure 4: The Timing of Events in the Partnership with Private Investment

Assumption: Assume Nash bargaining (with equal bargaining power)[28]. The outside

option for Continental is $\overline{B}_c$, which is its benefit without cooperation with Dupont. Dupont

can find an alternative partner, we assume its outside option to be $\overline{B}_d$.

---

[28] This assumption has been frequently used in property rights literature, for example, in Hart (1995) Chapter 2. However, the bargaining powers of DuPont and Continental may not be so balanced to give a 50:50 split of ex post surplus. Continental may face competition from other grain companies, which will reduce its bargaining power. However, as long as there is relationship-specific investment and Continental is the most efficient partner, it will get a positive share of the ex post surplus. In the meantime, $\overline{B}_d$ serves as a gauge of competition as well. Higher $\overline{B}_d$ indicates more intensive competition.

The bargaining solution with equal bargaining power will lead to an even division of the surplus. The surplus for each firm is,

Continental:

$$\overline{B}_c + \frac{1}{2}\left[r(s,Y) + (\beta - \gamma)Y(i,\gamma,s) - VC(Y,I) - \overline{B}_c - \overline{B}_d\right] = \frac{1}{2}B(i,I) + \frac{1}{2}\overline{B}_c - \frac{1}{2}\overline{B}_d \quad \text{(10-C)}$$

DuPont:

$$\overline{B}_d + \frac{1}{2}\left[r(s,Y) + (\beta - \gamma)Y(i,\gamma,s) - VC(Y,I) - \overline{B}_c - \overline{B}_d\right] = \frac{1}{2}B(i,I) - \frac{1}{2}\overline{B}_c + \frac{1}{2}\overline{B}_d \quad \text{(10-D)}$$

Subtracting the costs, the payoffs are respectively:

Continental:

$$\overline{B}_c + \frac{1}{2}\left[r(s,Y) + (\beta - \gamma)Y(i,\gamma,s) - VC(Y,I) - \overline{B}_c - \overline{B}_d\right] - C(I) - F$$

$$= \frac{1}{2}B(i,I) + \frac{1}{2}\overline{B}_c - \frac{1}{2}\overline{B}_d - C(I) - F$$

$$\text{(11-C)}$$

DuPont.

$$\overline{B}_d + \frac{1}{2}\left[r(s,Y) + (\beta - \gamma)Y(i,\gamma,s) - VC(Y,I) - \overline{B}_c - \overline{B}_d\right] - c(i)$$

$$= \frac{1}{2}B(i,I) - \frac{1}{2}\overline{B}_c - \frac{1}{2}\overline{B}_d - c(i)$$

$$\text{(11-D)}$$

Under the specified timing structure, the second stage decision (determining γ and s) is the same as that of (4). We expect (γ, s) to be determined optimally for given actions (i, I). Even if the timing structure is different, as long as renegotiations are allowed, the result will be the same. The first stage decision problem becomes one of choosing (i, I), where (γ, s) are functions of (i, I).

The first best levels of (i^*, I^*) are obtained by maximizing the total

surplus $TS = B(i, I) - F - c(i) - C(I)$ in equation (9) which is the same as the sum of the two

individual payoffs in (11-C) and (11-D). The first order conditions for interior solutions are:

$$i : \frac{\partial B(i, I)}{\partial i} - \frac{\partial c(i)}{\partial i} = 0$$
$$I : \frac{\partial B(i, I)}{\partial I} - \frac{\partial C(I)}{\partial I} = 0 \quad (12)$$

However, the two firms will maximize their individual payoffs, denote the result as

$(\tilde{i}, \tilde{I})$. And the first order conditions for interior solutions are respectively:

$$i : \frac{1}{2} \frac{\partial B(i, I)}{\partial i} - \frac{\partial c(i)}{\partial i} = 0 \quad (13\text{-}D)$$

$$I : \frac{1}{2} \frac{\partial B(i, I)}{\partial I} - \frac{\partial C(I)}{\partial I} = 0 \quad (13\text{-}C)$$

Equations in (12) and (13) differ because when there is joint maximization, levels of

investments (i and I) are coordinated to achieve the highest joint surplus. If the investment

variables i and I are chosen independently to maximized individual payoffs, there will be no

coordination of the levels of i and I, and total surplus must be less than the one that is

obtained when both variables are chosen simultaneously.

Assume that the second order sufficient conditions are satisfied. Solving (13-C) and

(13-D) jointly will give $(\tilde{i}, \tilde{I})$. Compare (13-C&D) with (12), with the assumption that

$\frac{\partial B(i, I)}{\partial i} > 0, \frac{\partial B(i, I)}{\partial I} > 0$, we will have $\tilde{i} < i^*$, or $\tilde{I} < I^*$ or both when $\varphi_{il} = B_{il} < 0$(See

Appendix 2-D and Figure 5-A. The proof is similar to that for Proposition 1 in section

4.4.1). At least one and possibly both firms will underinvest in noncontractible efforts.

When $\varphi_{iI} = B_{iI} > 0$, i.e., the private investments of DuPont and Continental are

complementary inputs, we will have $\tilde{i} < i^*$ and $\tilde{I} < I^*$ (see Figure 5-B), i.e., both firms

underinvest. This second scenario holds when the marginal productivity of one party

increases with the level of the other party's investment, which is more likely in this project.

The underinvestments happen even if (γ, s) are contractible, because for every fixed (γ, s),

at least one and possibly two firms will underinvest. The underinvestment problem arises

from the fact that each party gets less than the full benefit of their private effort. In this case,

they get only half of it (13-C. 13-D).

$(\tilde{i}, \tilde{I})$ lies in the shaded area.
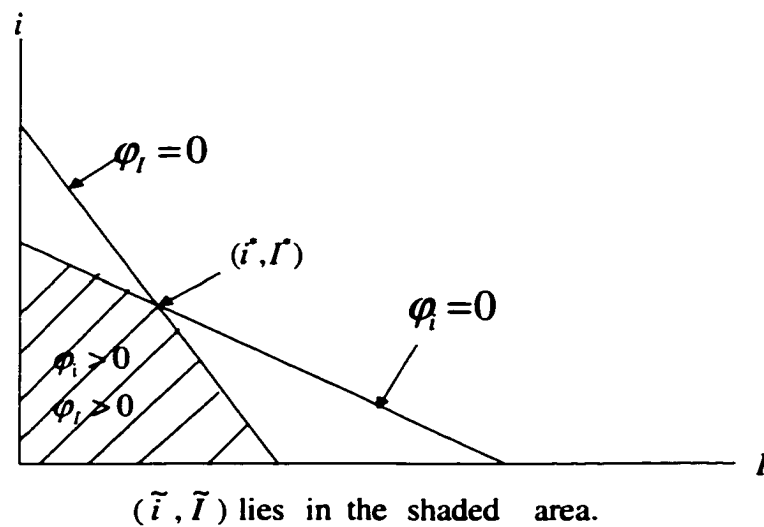
Figure 5-A: A Graphic Proof of the Result in 4.4.2 ($\varphi_{iI} = B_{iI} < 0$)
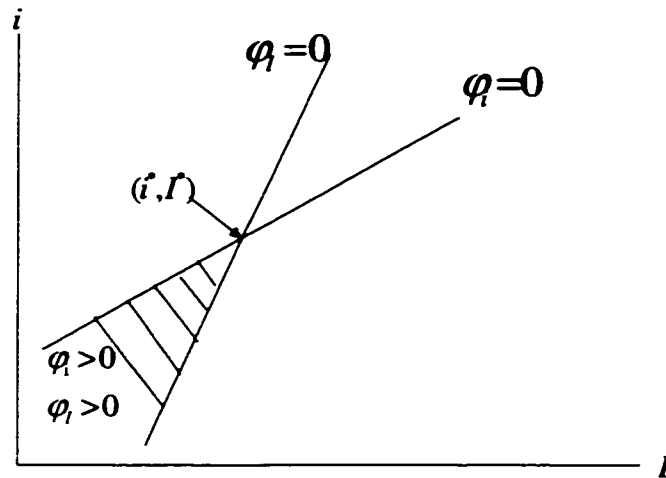
$(\tilde{i}, \tilde{I})$ lies in the shaded area.

Figure 5-B: A Graphic Proof of the Result in 4.4.2 ($\varphi_{iI} = B_{iI} > 0$)

4.4.3 An Extension with Variable Outside Options

We have assumed for simplicity in section 4.4.2 that the outside options for DuPont

and Continental are fixed. A closer examination shows that they might very well depend on

the private investments of the firms. DuPont's investment in the continuous improvement of

HOC's performance and technical assistance to growers will increase the value of the

project whichever the partner it chooses; the second best partner will also benefit had it been

choosen. Continental's private effort at cost control and marketing will improve its prospect

without participating in the HOC value chain too. The question that entails then is: how will

this affect the two firms' incentives to make private investments? However, the relative

magnitude of private investments' effects on the first best alliances and on the outside

options will differ. The marginal contributions of the private investments to the alliances

will be generally higher than to the second best partners.

Let $\overline{Bd}(i)$, $\overline{Bc}(I)$ be the outside options of DuPont and Continental respectively,

then the payoffs after bargaining are:

Continental: $\dfrac{1}{2}B(i,I)+\dfrac{1}{2}\overline{Bc}(I)-\dfrac{1}{2}\overline{Bd}(i)-C(I)-F$

DuPont: $\dfrac{1}{2}B(i,I)-\dfrac{1}{2}\overline{Bc}(I)+\dfrac{1}{2}\overline{Bd}(i)-c(i)$

The first order conditions for interior solutions to their decisions are:

$$I:\frac{1}{2}\frac{\partial B(i,I)}{\partial I}+\frac{1}{2}\frac{\partial \overline{Bc}(I)}{\partial I}-\frac{\partial C(I)}{\partial I}=0$$

$$i:\frac{1}{2}\frac{\partial B(i,I)}{\partial i}+\frac{1}{2}\frac{\partial \overline{Bd}(i)}{\partial i}-\frac{\partial c(i)}{\partial i}=0 \tag{14}$$

Denote the solution to (14) as $(\hat{i},\hat{I})$.

Assume that the value of outside options increase with the private investment level,

i.e., DuPont and Continental will benefit from their private investment and that benefit is

positively related to the level of that investment even if they don't form an alliance. Then,

evaluating (14) at $(\tilde{i},\tilde{I})$ gives:

$$i:(\frac{1}{2}\frac{\partial B(i,I)}{\partial i}+\frac{1}{2}\frac{\partial \overline{Bd}(i)}{\partial i}-\frac{\partial c(i)}{\partial i})\bigg|_{(\tilde{i},\tilde{I})}>0$$

$$I:(\frac{1}{2}\frac{\partial B(i,I)}{\partial I}+\frac{1}{2}\frac{\partial \overline{Bc}(I)}{\partial I}-\frac{\partial C(I)}{\partial I})\bigg|_{(\tilde{i},\tilde{I})}>0$$

As long as the private investments are to a certain degree relationship

specific $\left(\dfrac{\partial B(i,I)}{\partial i}>\dfrac{\partial \overline{Bd}(i)}{\partial i}\ \text{and}\ \dfrac{\partial B(i,I)}{\partial I}>\dfrac{\partial \overline{Bc}(I)}{\partial I}\right)$, evaluating (14) at (i^{*},I^{*}) will give:

$$i : (\frac{1}{2}\frac{\partial B(i,I)}{\partial i} + \frac{1}{2}\frac{\partial \bar{B}d(i)}{\partial i} - \frac{\partial c(i)}{\partial i})\bigg|_{(i^*,I^*)} < 0$$

$$I : (\frac{1}{2}\frac{\partial B(i,I)}{\partial I} + \frac{1}{2}\frac{\partial \bar{B}c(I)}{\partial I} - \frac{\partial C(I)}{\partial I})\bigg|_{(i^*,I^*)} < 0$$

Using the same method as in Appendix 2.D, we get the Figure 6-A when $B_{iI} < 0$, and

Figure 6-B when $B_{iI} > 0$.

Therefore, we will have $\hat{i} > \tilde{i}$, and/or $\hat{I} < \tilde{I}$, or both when $B_{iI} < 0$. At lease one

firm will invest more in private effort with variable outside options than with fixed outside

options. When $B_{iI} > 0$, $\hat{i} > \tilde{i}$ and $\hat{I} < \tilde{I}$, and both firms invest more with certainty in

private effort with variable outside options. Then, with very high probability, both private

investment levels are higher with variable outside options than with fixed outside options.

The implication here is that if both firms underinvest in uncontractible efforts with fixed

outside options, efforts that positively affect the outside options can lessen the degree of

underinvestment and partially solve the problem.

Given that the marginal contributions of i, I to the alliance are generally higher than

the contribution of i, I to the outside options $\left(\frac{\partial B(i,I)}{\partial i} > \frac{\partial \bar{B}d(i)}{\partial i}\right.$ and $\left.\frac{\partial B(i,I)}{\partial I} > \frac{\partial \bar{B}c(I)}{\partial I}\right)$, we

will have $\hat{i} < i^*$, and/or $\hat{I} < I^*$, or both when $B_{iI} < 0$. We will have $\tilde{i} < \hat{i} < i^*$ and

$\tilde{I} < \hat{I} < I^*$ unambiguously when $B_{iI} > 0$. Therefore, both firms will still likely underinvest

under (14), albeit to a lesser degree.

Noticeably, if $\frac{\partial \bar{B}c(I)}{\partial I} = 0$, then

$$\frac{1}{2}\frac{\partial B(i,I)}{\partial I}+\frac{1}{2}\frac{\partial \bar{B}c(I)}{\partial I}-\frac{\partial C(I)}{\partial I}=0$$

$$\frac{1}{2}\frac{\partial B(i,I)}{\partial i}+\frac{1}{2}\frac{\partial \bar{B}d(i)}{\partial i}-\frac{\partial c(i)}{\partial i}=0$$

$(\tilde{i},\tilde{I})$ lie in the shaded area BOD and

(i^*,I^*) lie in the shaded area AOC.

Figure 6-A: A Graphic Proof of the Result in 4.4.3 ($B_{iI}<0$)

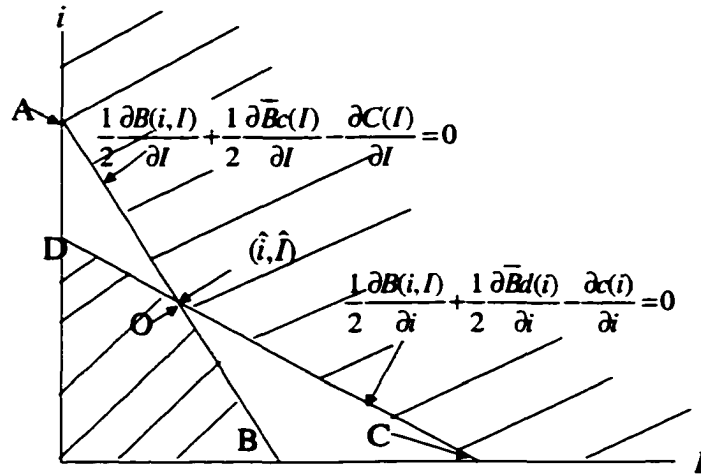$$\frac{1}{2}\frac{\partial B(i,I)}{\partial I}+\frac{1}{2}\frac{\partial \bar{B}c(I)}{\partial I}-\frac{\partial C(I)}{\partial I}=0$$
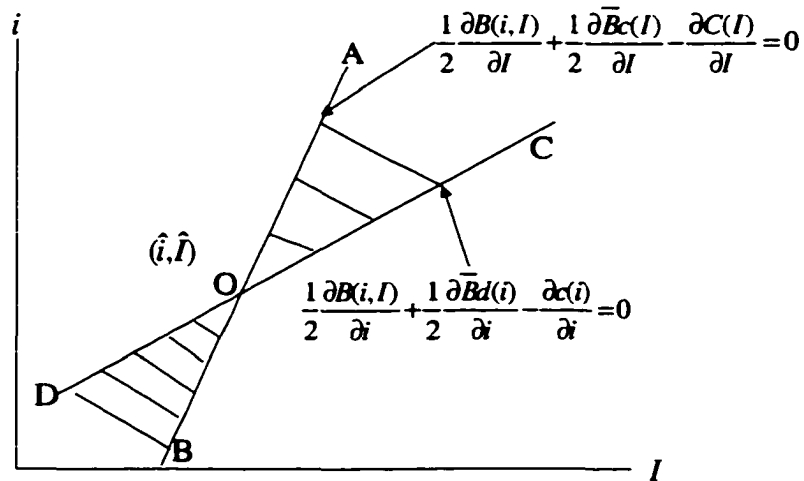
$$\frac{1}{2}\frac{\partial B(i,I)}{\partial i}+\frac{1}{2}\frac{\partial \bar{B}d(i)}{\partial i}-\frac{\partial c(i)}{\partial i}=0$$

$(\tilde{i},\tilde{I})$ lie in the shaded area BOD and

(i^*,I^*) lie in the shaded area AOC.

Figure 6-B: A Graphic Proof of Result in 4.4.3 ($B_{iI}>0$)

$$i : (\frac{1}{2}\frac{\partial B(i,I)}{\partial i} + \frac{1}{2}\frac{\partial \overline{B}d(i)}{\partial i} - \frac{\partial c(i)}{\partial i})\bigg|_{(\tilde{i},\tilde{I})} > 0$$

$$I : (\frac{1}{2}\frac{\partial B(i,I)}{\partial I} + \frac{1}{2}\frac{\partial \overline{B}c(I)}{\partial I} - \frac{\partial C(I)}{\partial I})\bigg|_{(\tilde{i},\tilde{I})} = 0$$

and $(\tilde{i},\tilde{I})$ will lie on the segment OB in Figure 6-A, which gives: $\hat{i} > \tilde{i}$ and $\hat{I} < \tilde{I}$.

If $\dfrac{\partial \overline{B}d(i)}{\partial i} = 0$, then

$$i : (\frac{1}{2}\frac{\partial B(i,I)}{\partial i} + \frac{1}{2}\frac{\partial \overline{B}d(i)}{\partial i} - \frac{\partial c(i)}{\partial i})\bigg|_{(\tilde{i},\tilde{I})} = 0$$

$$I : (\frac{1}{2}\frac{\partial B(i,I)}{\partial I} + \frac{1}{2}\frac{\partial \overline{B}c(I)}{\partial I} - \frac{\partial C(I)}{\partial I})\bigg|_{(\tilde{i},\tilde{I})} > 0$$

and $(\tilde{i},\tilde{I})$ will lie on the segment DO in Figure 6, which gives $\hat{i} < \tilde{i}$ and $\hat{I} > \tilde{I}$.

In other words, the existence of a positive effect of one party's private investment on its outside option in the absence of another will alleviate its own underinvestment problem but aggravate that of the other party when $B_{iI} < 0$. If DuPont's outside option is more affected by its own private investment and the effect of Continental's private investment on its outside option is minimal, then DuPont's incentive problem is less severe; and vice versa. In summary, fixed outside options for each firm will lead to underinvestment by one or both firms compared to the maximization of joint surplus, variable outside options or the ability of the firms to affect the payoffs to the outside options, will lessen this effect. In Figure 6-A, the optimal solution with variable outside options just between the set of investment levels maximizing joint surplus (AOC) and those maximizing individual surplus with fixed options (BOD).

4.5 Comparison of Different Ownership Structures

The socially optimal private efforts would be those that maximize the total surplus of

the project, i.e., (i^*, I^*) that are defined by equations in (12).

$\max\limits_{i, I} TS = B(i, I) - F - c(i) - C(I)$ and the first order conditions are:

$$i : \frac{\partial B(i, I)}{\partial i} - \frac{\partial c(i)}{\partial i} = o$$

$$I : \frac{\partial B(i, I)}{\partial I} - \frac{\partial C(I)}{\partial I} = 0 \quad (12)$$

The total surplus achieved in the first best is: $TS^o = B(i^*, I^*) - F - c(i^*) - C(I^*)$

We have seen in the previous section that when DuPont and Continental are separate

firms with equal bargaining power, the bargaining will lead to sharing of the total surplus of

the project, and private efforts $(\tilde{i}, \tilde{I})$ are defined by equations in (13).

$$i : \frac{1}{2}\frac{\partial B}{\partial i} - \frac{\partial c(i)}{\partial i} = o$$

$$I : \frac{1}{2}\frac{\partial B}{\partial I} - \frac{\partial C(I)}{\partial I} = 0 \quad (13)$$

The total surplus resulting in the nonintegrated case is:

$$TS^n = B(\tilde{i}, \tilde{I}) - F - c(\tilde{i}) - C(\tilde{I})$$

If one party has the full ownership of the project, it will have the full incentive to do

private investment since it will enjoy the full benefit of its investment; while the other party,

deprived of the right to enjoy the benefit of its private effort, will have no incentive to invest

in unobservable private efforts. The minimum level of private effort by the employed party

will be the level of effort induced by the employees' ego, career concern and prospects of

informal rewards[29]. We can normalize this minimum level of effort as 0.

The decision-makings in the presence of integration are respectively:

Integration by Continental: $i=0$ and I is chosen to maximize

$$TS = B(i = 0, I, \gamma, s) - F - C(I)$$

And first order condition is:

$$\frac{\partial B(i = 0, I)}{\partial I} - \frac{\partial C(I)}{\partial I} = 0$$

Integration by Dupont: $I=0$ and i is chosen to maximize

$$TS = B(I = 0, i, \gamma, s) - F - c(i)$$

And first order condition is:

$$\frac{\partial B(I = 0, i)}{\partial i} - \frac{\partial c(i)}{\partial i} = o$$

We say one party's private investment is not important if its marginal impact on the

total surplus is approximately zero for any positive level of that investment[30]. And the fact

that there is strictly positive cost associated with exerting any positive level of effort will

make the optimal level of this party's investment to be the minimum level. This implies

acquisition of the physical assets of a party whose private effort is not important won't affect

the total surplus, in which case the optimal ownership structure will be determined by the

other party's private investment. When the other party's private investment is important,

---

[29] This assumption is same as those made in Aghion & Tirole (1994).

[30] If the second order conditions are satisfied, i.e., $\dfrac{\partial^2 B}{\partial i^2} \leq 0$, then $\dfrac{\partial B(i = 0)}{\partial i} \approx 0$ will suffice.

integration by the other party is optimal. When both parties' private efforts are not important, optimal ownership structure will be determined by other factors.

If Dupont's private investment is not important, then $i^* \cong 0$. Integration by Continental won't affect the total surplus. If Continental's private is important, then the best ownership structure will be integration by Continental, and Dupont should sell the technology and technical services to Continental, if feasible. This is hardly the case since the biotechnology is in the rapidly innovating stage, while grain business is a relatively mature and stable business. We haven't seen any grain company that bought out a seed technology and used it exclusively. In fact, we have seen Cargill sell off its seed divisions and set up joint ventures with Monsanto.

If Continental's private investment is not important, then $I^* \cong 0$. Integration by DuPont will not affect the total surplus. It will be optimal for Dupont to integrate forward into the marketing stage.

When $i^* >> 0, I^* >> 0$, i.e., private investments by both parties are important, non-integration represented by (13) is the optimal ownership structure. Both parties' incentives to invest will be preserved to a certain extent, although not completely. This is a second best solution to the uncontractibility problem. All the conclusions above have implicitly assumed total surplus achieved by the specified ownership structure is larger than that of the outside option, namely $TS > \bar{B} + 0 = \bar{B}$. Otherwise, the best they can do is to undertake the alternatives.

We have assumed that DuPont and Continental have equal bargaining power so far. However, if one party has all the bargaining power, the conclusions can differ. In fact, the

bargaining power can serve as a substitute for integration when one party doesn't contribute important private effort. For instance, when Continental's private effort is not important while that of DuPont is, if DuPont has all the bargaining power, it can extract all the surplus by paying a marketing fee to Continental.

We can also argue that ownership structure evolves as technology and the nature of the project change over time, which is the norm of business life. The importance of private efforts changes as a new technology matures and a project is established to do repeated trades. The productivity of a party's private effort may increase or diminish over time, so will its control of the project.

4.6 A Dynamic Model

Dynamics may be a key factor in shaping the partnership between the seed technology provider and downstream firms. More value-enhanced grains are being developed and are expected to be introduced into the market in the near future (see Table 1 and Table 2). This prospect will have a significant impact on decisions made today. Specifically, forward-looking agents will take the effect of present investments on the future gains into consideration.

In the case of HOC, the current actions of DuPont and the grain handler can influence the future gains through several channels. One is the positive externality rising from learning- by- doing. One of the obstacles to commercialize HOC- a new product- is the lack of information and thus interests from growers and end-users. Efforts to provide assistance and information to growers and end-users will have a positive impact on the acceptance of new value-enhanced products. Evidence shows that lack of information is one

Table 4.1 Pipeline of Biotechnology Quality Traits in Major Crops

Product	Technology	Developmental stage	Value
Corn	High lysine	Pre-commercial	Moderate to Low
	Low N fertilizer need	R&D	High
	Low Phytate	R&D	Moderate
	Modified starch	Pre-commercial	Low
	Phyto-manufacturing	R&D	Moderate
Soybeans	High oleic	Commercial	Moderate/high
	Improved protein	Pre-commercial	High
	High stearic	Pre-commercial	Low
	Phyto-manufacturing	R&D	Low
Canola	High laurate	Pre-commercial	Low
	High oleic/low	Pre-commercial	High
	linoleic	R&D	Low
	High saturates	Pre-commercial	Low/moderate
	High erucid	R&D	Low
	Phyto-manufacturing		

Source: Developed through personal interviews with leading biotechnology developers.
Phyto-manufacturing, also known as molecular farming, involves production of substances at molecular levels (e.g., enzymes, plantibodies).
Kalaitzandonakes, Nicholas, and Richard Maltsbarger, Biotechonology and Identity-Preserved Supply Chains. Choices, Fourth Quarter 1998, pp16 Table 1

Table 4.2 OPTIMUM Quality Grain's Product Pipeline

Year	Product
Corn	
1998	HOC+high oleic
1999	HOC+high lysine
2001	HOC+high lysine+high methionine
Soybeans	
1997	High oleic
2000	High lysine
2001	High lysine+high oleic
2001	High lysine+high methionine
2002	High oleic+low saturate+high lysine, high methionine

Source: OPTIMUM Quality Grains.

factor influencing some growers in their decisions not to produce value-enhanced corn.

Growers having previous experience with one type of value-enhanced grain production are

more likely to participate in programs involving the other types (U.S. Feed Grain Council,

1998). A grower may improve production efficiency as he becomes more familiar with the

new crop. A better-informed grower is more likely to try a new crop. Therefore, the grower

base will be enlarged in the future value-enhanced grains. As for the end-users, they need to

be convinced of the added value of value-enhanced grains to be willing to pay a premium

for them. Lack of information was found to be a factor impeding the acceptance of value-

enhanced corns (U.S. Feed Grain Council, 1998). The end-users will learn more about the

value of the new products in the process of using them, and in the meantime, learn how to

use them more efficiently by optimizing feed rations, etc. So marketing efforts today also help create a customer base for the future. The marketing firms- DuPont , Continental, ADM and ConAgra, will learn over time and become more efficient in disseminating information, which will make their future efforts more effective and cost efficient.

Another reason for improved results over time in commercializing value-enhanced products is specific to the incumbents of an on-going relationship, relationship-specific human capital. Specialty grains require close coordination along the supply chain, and DuPont formed an alliance with Continental to create a market for HOC. To set up and coordinate a contractual relationship requires investment in not only tangible assets such as those used in communication, but more importantly in human capital. The human personnel involved develop a particular knowledge about the relationship, which facilitates the carrying out of the coordination. This human capital is specific to the relationship and valuable only within the relationship. Its existence gives the incumbent firms an advantage over potential partners. In fact, when new products are marketed, Continental, having invested in both physical and human assets, may have a first mover advantages over its rivals. The physical assets could be communication equipment specific to the relationship, and/or facilities customized to handle the relatively small volume of specialty grain in an identity-preserved way. However, there is always a possibility that a potential competitor may overtake an incumbent by leapfrogging on managerial expertise and technology.

The dynamic factor will inevitably affect the investment incentives and participation decisions in the partnership. The benefit expected in the future will provide additional incentive to invest today and makes the relationship more profitable than otherwise. The ideas are formalized below.

4.6.1 A Simplified Model

The set up

- Assume there are two periods, t=0, and t=1. At t=0, HOC is the product. At t=1, a different new value-enhanced product will be introduced to the market.

- Time preference parameter is ρ.

- To simplify, assume that there is no active competition with Continental in either period and DuPont and Continental remain partners in the second period. In both periods, the outside options of both firms are fixed. The outside options at t=0 are the same as before, while those at t=1 denoted as $\overline{Bc}1, \overline{Bd}1$ [31] for Continental and DuPont.

- To embody the effect of current investment on the future gains, total surplus $TS1$ at t=1 is denoted as a function of investments' level at t=0, i, I, and increasing with both arguments. Namely, $TS1(i, I)$ with $\dfrac{\partial TS(i, I)}{\partial i} > 0$ and $\dfrac{\partial TS(i, I)}{\partial I} > 0$.

Given these assumptions, the payoffs to the firms discounted to t=0 are respectively,

Continental: $\dfrac{1}{2}B(i, I) + \dfrac{1}{2}\overline{B} - C(I) - F + \rho\left[\dfrac{1}{2}TS1(i, I) + \dfrac{1}{2}\overline{Bc}1 - \dfrac{1}{2}\overline{Bd}1\right]$

DuPont: $\dfrac{1}{2}B(i, I) - \dfrac{1}{2}\overline{B} - c(i) + \rho\left[\dfrac{1}{2}TS1(i, I) - \dfrac{1}{2}\overline{Bc}1 + \dfrac{1}{2}\overline{Bd}1\right]$

As before, assuming that the second order sufficient conditions are satisfied, the first order conditions for interior solutions are respectively,

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[31] It is more desirable to make $\overline{Bd}1$ dependent on i, but the results are the same regardless.

$$I : \frac{1}{2}\frac{\partial B(i,I)}{\partial I} - \frac{\partial C(I)}{\partial I} + \rho\frac{1}{2}\frac{\partial TS1(i,I)}{\partial I} = 0$$

$$i : \frac{1}{2}\frac{\partial B(i,I)}{\partial i} - \frac{\partial c(i)}{\partial i} + \rho\frac{1}{2}\frac{\partial TS(i,I)}{\partial i} = 0 \qquad (15)$$

Denote the solution to (15) as $(\bar{i},\bar{I})$.

Evaluating (13) at $(\bar{i},\bar{I})$ gives:

$$i : \left(\frac{1}{2}\frac{\partial B(i,I)}{\partial i} - \frac{\partial c(i)}{\partial i}\right)\Big|_{(\bar{i},\bar{I})} < 0$$

$$I : \left(\frac{1}{2}\frac{\partial B(i,I)}{\partial I} - \frac{\partial C(I)}{\partial I}\right)\Big|_{(\bar{i},\bar{I})} < 0 \qquad (13')[32]$$

Using the same techniques employed in section 4.2 and Appendix 2D, we can draw

the graphs below. Figure 7-A is when $B_{iI} < 0$ and Figure 7-B is when $B_{iI} > 0$.

$(\bar{i},\bar{I})$ lies in the shaded area.
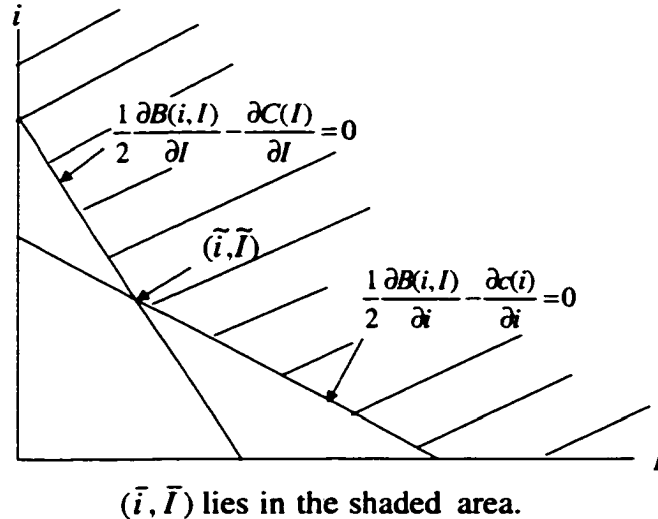
Figure 7-A: A Graphic Proof of Result in 4.6.1 ($B_{iI} < 0$)

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[32] This is because of the assumptions of $\rho\frac{\partial TS(i,I)}{\partial i} > 0$ and $\rho\frac{\partial TS(i,I)}{\partial I} > 0$.
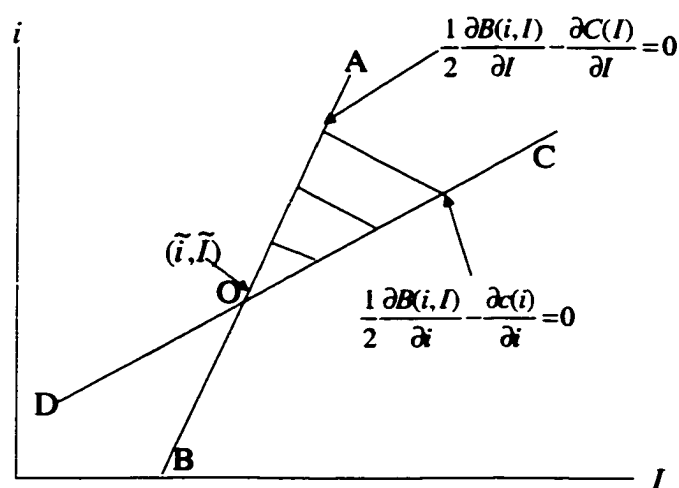
$(\tilde{i}, \tilde{I})$ lie in the shaded area AOC.

Figure 7-B: A Graphic Proof of Result in 4.6.1 ($B_{iI} > 0$)

From Figure 7-A, we will get $\bar{i} > \tilde{i}$, and/or $\bar{I} > \tilde{I}$, or both. From Figure 7-B, both

$\bar{i} > \tilde{i}$ and $\bar{I} > \tilde{I}$ hold. This implies that both parties are likely to make more private

investment when future gains depend on current investment level, which is socially

preferred when both are underinvesting in the static model relative to the optimal solutions.

Long term relationships help to mitigate private incentive problems. In fact, when the firms

are sufficiently patient and the impact of current investment on the future gain is big enough,

overinvestment is possible. However, the rapid pace of industry change tends to moderate

patience.

With the future gains taken into account, if $\Delta = TS1(i, I) - \overline{Bc}1 - \overline{Bd}1 \geq 0$, i.e., the

new product is preferable to other outside options in the second period, HOC is more likely

to be marketed in the first period, and both firms are more likely to take part in the partnership. With no consideration for the future, the participation rules for Continental and DuPont are given in (16-C) and (16-D) respectively,

Continental: $\dfrac{1}{2}B(i,I)+\dfrac{1}{2}\overline{Bc}-\dfrac{1}{2}\overline{Bd}-C(I)-F \geq \overline{Bc}$ (16-C)

DuPont: $\dfrac{1}{2}B(i,I)-\dfrac{1}{2}\overline{Bc}+\dfrac{1}{2}\overline{Bd}-c(i) \geq \overline{Bd}$ (16-D)

With a second period product, their participation rules are given in (17-C) and (17-D):

Continental:

$$\frac{1}{2}B(i,I)+\frac{1}{2}\overline{Bc}-\frac{1}{2}\overline{Bd}-C(I)-F+\rho\left[\frac{1}{2}TS1(i,I)+\frac{1}{2}\overline{Bc1}-\frac{1}{2}\overline{Bd1}\right] \geq \overline{Bc}+\rho\overline{Bc1} \qquad (17\text{-}C)$$

DuPont:

$$\frac{1}{2}B(i,I)-\frac{1}{2}\overline{Bc}+\overline{Bd}-c(i)+\rho\left[\frac{1}{2}TS1(i,I)-\frac{1}{2}\overline{Bc1}+\frac{1}{2}\overline{Bd1}\right] \geq \overline{Bd}+\rho\overline{Bd1} \qquad (17\text{-}D)$$

Which are equivalent to:

Continental: $\dfrac{1}{2}B(i,I)+\dfrac{1}{2}\overline{Bc}-\dfrac{1}{2}\overline{Bd}-C(I)-F+\rho\Delta \geq \overline{Bc}$ (18-C)

DuPont: $\dfrac{1}{2}B(i,I)+\dfrac{1}{2}\overline{Bd}-\dfrac{1}{2}\overline{Bc}-c(i)+\rho\Delta \geq \overline{Bd}$ (18-D)

When the future product is more profitable than other options ($\Delta \geq 0$), equations in

(18) are more likely to hold than those in (16)[33]. Therefore, the probability of forming

partnership in the first period is higher than without the future profitable product. If the

future gain Δ is big enough, it could happen that one of the firms enters the relationship at a

first period loss. Clearly when $\Delta < 0$, this partnership to commercialize future value-

enhanced products in the second period is not desirable and should not be undertaken. A

possible scenario - a more competitive grain firm takes up the venture - is presented in the

next model.

4.6.2 A More General Model That Accounts For Incumbent Advantage

Assume as before there are two periods, t=0, and t=1. At t=0, HOC is the product. At

t=1, another new proprietary value-enhanced product will be introduced to the market.

Without loss of generality, assume the time preference parameter $\rho = 1$.

The incumbent advantage comes from two sources - specialized physical assets and

relationship-specific human capital. In the case of specialty grain, the specialized assets are

small bins and other equipment designed for identity preservation; relationship-specific

human capital is expertise developed over the process of coordination that reduces

transaction costs and improves the effectiveness and efficiency of communication,

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[33] Because $\dfrac{1}{2}B(i,I) + \dfrac{1}{2}\overline{Bc} - \dfrac{1}{2}\overline{Bd} - C(I) - F + \rho\Delta > \dfrac{1}{2}B(i,I) + \dfrac{1}{2}\overline{Bc} - \dfrac{1}{2}\overline{Bd} - C(I) - F$ and

$\dfrac{1}{2}B(i,I) + \dfrac{1}{2}\overline{Bd} - \dfrac{1}{2}\overline{Bc} - c(i) + \rho\Delta > \dfrac{1}{2}B(i,I) + \dfrac{1}{2}\overline{Bd} - \dfrac{1}{2}\overline{Bc} - c(i)$ $\forall (i,I)$,

(18-C) holds $\Rightarrow$ (16-C) holds, but that (16-C) holds does not necessary lead to (18-C). Similarly, (18-D) holds $\Rightarrow$ (16-D) holds, but not the other way around.

promptness in identifying and solving problems, and it also includes the experience gained in dealing with the end-users in marketing.

The previous simplified model assumes away competition in the second period. In a dynamic business world, competition is a constant norm rather than exception. New innovative firms emerge to challenge established ones through improved production and organization efficiencies. The competitiveness of established firms also changes over time. Therefore, at t=1, Continental's status as the best partner will be challenged by potential competitors. If a more efficient competitor emerges, and the benefit to DuPont of switching partners outweighs the incumbent advantage, then Continental will lose the business. This will inevitably influence forward-looking agents' decisions at the first period.

Assume that the problem facing a rival R's partnership with DuPont is essentially the same as the one faced by the partnership between DuPont and Continental in the first period, which was given in Section 4.4. The total surplus distribution rule is also bargaining with equal bargaining power. As argued before, DuPont's first period private investment i will affect the second period surplus in a positive way, and this impact will be carried over to alliance with other partners. A rival can outperform Continental in the second period by dramatically lowering variable cost despite Continental's incumbent advantage.

Let us denote the total surplus achievable by a partnership between DuPont and R as $TS_1^R(i^0)$, where i^0 is DuPont's first period private investment i represented explicitly by its timing factor. Assume $TS_1^R(i^0)$ increases with i^0 $\left(\dfrac{\partial TS_1^R(i^0)}{\partial i^0} > 0 \right)$.

The total surplus achievable by the partnership between DuPont and Continental in the second period is denoted as $TS_1^C(i^0, I^0, F^0)$, where I^0 is the first period investment by

Continental, and F^0 is the first period fixed investment by Continental. The incumbent advantage can then be characterized by the fact that I^0, F^0 affect $TS_1^C(i^0, I^0, F^0)$ positively

in addition to i^0 $\left(\dfrac{\partial TS_1^C(i^0, I^0, F^0)}{\partial i^0} > 0, \dfrac{\partial TS_1^C(i^0, I^0, F^0)}{\partial I^0} > 0 \text{ and } \dfrac{\partial TS_1^C(i^0, I^0, F^0)}{\partial F^0} \right)$.

We say R outperforms Continental whenever $TS_1^R(i^0) > TS_1^C(i^0, I^0, F^0)$. Suppose the occurrence of this event will depend on the state of the world $\theta \in \Theta$, which is unknown in the first period. But the distribution of θ is known. For given θ,

$P(i^0, I^0, F^0) = \text{Prob}\left[TS_1^R(i^0) - TS_1^C(i^0, I^0, F^0) > 0 \right]$ will be inversely related to i^0, I^0,

and F^0, provided that $\dfrac{\partial TS_1^R(i^0)}{\partial i^0} < \dfrac{\partial TS_1^C(i^0, I^0, F^0)}{\partial i^0}$, i.e., i^0 (DuPont's first period

investment) is marginally more productive with the presence of incumbent advantage[34].

This gives: $\dfrac{\partial P(i^0, I^0, F^0)}{\partial i^0} < 0, \dfrac{\partial P(i^0, I^0, F^0)}{\partial I^0} < 0$ and $\dfrac{\partial P(i^0, I^0, F^0)}{\partial F^0} < 0$.

The setup of the model is as the following:

- The new product is very profitable and participation conditions are satisfied for all parties concerned.[35]

- At t=0, Continental is the most efficient partner whose partnership produces the highest joint surplus and is chosen to be the partner.

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[34] Since for given θ,

$\dfrac{\partial\left[TS_1^R(i^0) - TS_1^C(i^0, I^0, F^0) \right]}{\partial i^0} < 0, \dfrac{\partial\left[TS_1^R(i^0) - TS_1^C(i^0, I^0, F^0) \right]}{\partial I^0} = -\dfrac{\partial TS_1^C}{\partial I^0} < 0$ and

$\dfrac{\partial\left[TS_1^R(i^0) - TS_1^C(i^0, I^0, F^0) \right]}{\partial F^0} = -\dfrac{\partial TS_1^C}{\partial F^0} < 0$.

[35] The possible event that they are not satisfied can be accounted for by assigning a specific probability to it. As long as the payoffs are constant in that event, the results derived in the following model won't change.

- At t=1, with probability $1 - P(i^0, I^0, F^0)$ where

$$P(i^0, I^0, F^0) \leq \text{Prob}\left[TS_1^R(i^0) - TS_1^C(i^0, I^0, F^0) > 0\right],$$ Continental is the best partner

in marketing the new product. And Continental is chosen as the best partner. As in the

previous discussion, define Continental's outside option as the constant $\overline{Bc}1$ and

DuPont's as $\overline{Bd}1$. The payoffs are respectively,

Continental: $\dfrac{1}{2} TS_1^C(i^0, I^0, F^0) + \dfrac{1}{2}\overline{Bc}1 - \dfrac{1}{2}\overline{Bd}1$

DuPont: $\dfrac{1}{2} TS_1^C(i^0, I^0, F^0) - \dfrac{1}{2}\overline{Bc}1 + \dfrac{1}{2}\overline{Bd}1$

- At t=1, with probability $P(i^0, I^0, F^0)$, a rival R outperforms Continental and DuPont

gains more by choosing R as partner. And R is chosen as the best partner. The payoffs

are respectively,

Continental: $\overline{Bc}1$

DuPont: $\pi(i^0)$ $\quad$ $(\pi(i^0) > \dfrac{1}{2} TS_1^C(i^0, I^0, F^0) + \dfrac{1}{2}\overline{Bc}1 - \dfrac{1}{2}\overline{Bd}1)$

The total expected payoffs for the two firms when they make decisions at t=0 are:

Continental: $\dfrac{1}{2} B(i^0, I^0) + \dfrac{1}{2}\overline{B} - C(I^0) - F^0 +$
$\left[1 - P(i^0, I^0, F^0)\right]\left[\dfrac{1}{2} TS_1^C(i^0, I^0, F^0) + \dfrac{1}{2}\overline{Bc}1 - \dfrac{1}{2}\overline{Bd}1\right] + P(i^0, I^0, F^0)\overline{Bc}1$

DuPont: $\dfrac{1}{2} B(i^0, I^0) - \dfrac{1}{2}\overline{B} - c(i^0) +$
$\left[1 - P(i^0, I^0, F^0)\right]\left[\dfrac{1}{2} TS_1^C(i^0, I^0, F^0) - \dfrac{1}{2}\overline{Bc}1 + \dfrac{1}{2}\overline{Bd}1\right] + P(i^0, I^0, F^0)\pi(i^0)$

Assume second order conditions are satisfied, the first order conditions for interior

solutions are (19):

$$\frac{1}{2}\frac{\partial B(i^0, I^0)}{\partial I^0} - \frac{\partial C(I^0)}{\partial I^0} + [1 - P(i^0, I^0, F^0)]\frac{1}{2}\frac{\partial TS_1^C(i^0, I^0, F^0)}{\partial I^0}$$

$$-\frac{\partial P(i^0, I^0, F^0)}{\partial I^0}\left[\frac{1}{2}TS_1^C(i^0, I^0, F^0) - \frac{1}{2}\overline{B}c1 - \frac{1}{2}\overline{B}d1\right] = 0$$

$$\frac{1}{2}\frac{\partial B(i^0, I^0)}{\partial i^0} - \frac{\partial c(i^0)}{\partial i^0} + [1 - P(i^0, I^0, F^0)]\frac{1}{2}\frac{\partial TS_1^C(i^0, I^0, F^0)}{\partial i^0} + p(i^0, I^0, F^0)\frac{\partial \pi(i^0)}{\partial i^0}$$

$$-\frac{\partial P(i^0, I^0, F^0)}{\partial i^0}\left[\frac{1}{2}TS_1^C(i^0, I^0, F^0) - \frac{1}{2}\overline{B}c1 + \frac{1}{2}\overline{B}d1 - \pi(i^0)\right] = 0$$

Let

$$M^C = -p(i^0, I^0, F^0)\frac{1}{2}\frac{\partial TS_1^C(i^0, I^0, F^0)}{\partial I^0} - \frac{\partial P(i^0, I^0, F^0)}{\partial I^0}\left[\frac{1}{2}TS_1^C(i^0, I^0, F^0) - \frac{1}{2}\overline{B}c1 - \frac{1}{2}\overline{B}d1\right].$$

$$M^D = -p(i^0, I^0, F^0)\left[\frac{1}{2}\frac{\partial TS_1^C(i^0, I^0, F^0)}{\partial i^0} - \frac{\partial \pi(i^0)}{\partial i^0}\right]$$

then, (19) becomes (20),

$$-\frac{\partial P(i^0, I^0, F^0)}{\partial i^0}\left[\frac{1}{2}TS_1^C(i^0, I^0, F^0) - \frac{1}{2}\overline{B}c1 + \frac{1}{2}\overline{B}d1 - \pi(i^0)\right]$$

$$I^0 : \frac{1}{2}\frac{\partial B(i^0, I^0)}{\partial I^0} - \frac{\partial C(I^0)}{\partial I^0} + \frac{1}{2}\frac{\partial TS_1^C(i^0, I^0, F^0)}{\partial I^0} + M^C = 0$$

$$i^0 : \frac{1}{2}\frac{\partial B(i^0, I^0)}{\partial i^0} - \frac{\partial c(i^0)}{\partial i^0} + \frac{1}{2}\frac{\partial TS_1^C(i^0, I^0, F^0)}{\partial i^0} + M^D = 0$$

Denote the solutions to (20) as $(\bar{\bar{i}}, \bar{\bar{I}})$.

Comparing $(\bar{\bar{i}}, \bar{\bar{I}})$ with the solutions to (15)-$(\bar{i}, \bar{I})$-(by construction, $\rho = 1$,

$i = i^0, I = I^0$, and $TS1(i, I) = TS_1^C(i^0, I^0, F^0)$). Their relationship is dependent on the signs

of M^C and M^D and is ambiguous in general. Equations (15) give the case when the new

product is superior to other options and Continental has no competition from rivals and will

undertake the project with certainty. When competition comes along, it poses a possibility

that Continental won't get the benefit of its investment in the second period, while at the

same time, Continental can reduce this possibility by increasing its first period investment.

By the assumptions we have made about the relationship specificity of investment

and the bargaining rules, $M^D < 0$ [36]. But the sign of M^C is unambiguous.

Case 1: $M^C > 0$

This case results when gain from the new product $\left[TS_1^C(i^0, I^0, F^0) - \overline{B}c1 - \overline{B}d1\right]$ is

large, or the marginal impact of Continental's investment on the probability of R's

outperforming $(-\dfrac{\partial P(i^0, I^0, F^0)}{\partial I^0})$ is large, or both. In this case, the marginal benefit from

reducing the possibility of losing to R outweighs the expected loss from losing. Provided

that all the previous assumptions hold, we will get unambiguous result- $\overline{\overline{i}} < \overline{i}$, and $\overline{\overline{I}} > \overline{I}$;

i.e., Continental invests more and DuPont invests less in the presence of competition. The

intuition here is that competition in the second period improves the prospect for DuPont and

it is to its benefit to make the actual realization of competition more likely by reducing its

first period investment. To Continental, competition poses a threat of not being able to enjoy

superb gain in the second period, so it tries to decrease the possibility of the actual

realization of that threat.

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[36] By assumptions, $\dfrac{\partial P(i^0, I^0, F^0)}{\partial i^0} < 0$ and $\left[\dfrac{1}{2}TS_1^C(i^0, I^0, F^0) - \dfrac{1}{2}\overline{B}c1 + \dfrac{1}{2}\overline{B}d1 - \pi(i^0)\right] < 0$.

$\dfrac{\partial TS_1^R(i^0)}{\partial i^0} < \dfrac{\partial TS_1^C(i^0, I^0, F^0)}{\partial i^0}$ (investments are relationship specific) and equal bargaining power make

$\left[\dfrac{1}{2}\dfrac{\partial TS_1^C(i^0, I^0, F^0)}{\partial i^0} - \dfrac{\partial \pi(i^0)}{\partial i^0}\right] > 0$.

Case 2:

$$M^C = -p(i^0, I^0, F^0)\frac{1}{2}\frac{\partial TS_1^C(i^0, I^0, F^0)}{\partial I^0} - \frac{\partial P(i^0, I^0, F^0)}{\partial I^0}\left[\frac{1}{2}TS_1^C(i^0, I^0, F^0) - \frac{1}{2}\overline{B}c1 - \frac{1}{2}\overline{B}d1\right] < 0$$

This case results when gains from the new product $\left[TS_1^C(i^0, I^0, F^0) - \overline{B}c1 - \overline{B}d1\right]$ is

small or the marginal impact of Continental's investment on the probability of R's

outperforming $(-\frac{\partial P(i^0, I^0, F^0)}{\partial I^0})$ is small, or the probability of losing to R $\left[1 - P(i^0, I^0, F^0)\right]$ is

big, or all of them. With the assumptions we have made, we will get $\overline{\overline{i}} < \overline{i}$, or $\overline{I} < \overline{\overline{I}}$, or both.

DuPont underinvests in order to induce more competition, and Continental invests less

because the expected marginal benefit in the second period derived from its present

investment is reduced significantly by the high probability of losing to R and/or this

expected benefit is relatively small.

That DuPont will underinvest may sound counterintuitive. This hinges on the

assumptions that i^0 is marginally more productive inside the existing relationship and with

certain probability partnership with R produces a bigger payoff to DuPont. With R, i^0 is less

productive, and meanwhile, a smaller i^0 means a higher probability that R wins the project

resulting a bigger payoff.

In summary, firms' decisions on investing to achieve incumbent advantage are

contingent. The party (DuPont), which may stand to gain by changing business partners in

the future, is more likey to underinvest in an existing relationship versus when the

relationship is expected to continue with certainty. The party (Continental), which may stand

to lose by a dissolved relationship in the future, is likely to invest more when the stake in

losing is high and/or the incumbent advantage measured by the investment's impact on the

continuance of the relationship is high; and it tends to invest less when otherwise.

CHAPTER 5

EMPIRICAL EVALUATIONS OF THE THEORETICAL MODELS

Information that is relevant in evaluating the models presented in Chapter 4 comes

from the participants in the value chain, namely DuPont, the growers, elevators, Continental,

other grain firms, and end-users. Newspapers, trade journal articles, academic studies, and

surveys by concerned organizations provide a fairly good amount of this information. The

evidence collected mostly confirms the assumptions and the results of the various models.

5.1 Survey Administered by the U.S. Feed Grain Council

Theoretical results from the previous chapter are generally supported by the findings

of surveys regarding VEC (value-enhanced corn)[37] which were conducted by the U.S. Feed

Grains Council. Although the survey was not targeted solely at HOC, HOC is found to be

the most commonly grown and the fastest growing type of VEC as defined by the Council.

And the generality of the survey questions allows for easy use in evaluating the HOC. The

Council has compiled test and survey results and analysis of the VEC market in the main

corn producing states since the 1995/96 growing season. The majority of data collection has

been concentrated in the top seven corn exporting states- Illinois, Iowa, Nebraska, Indiana,

Minnesota, Ohio, and Missouri. In 1997/98, 5535 surveys were sent to grain producers in

the region. 1837 responses were received in 1997. Findings that are relevant in evaluating

the models in this paper are summarized below.

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[37] VEC is defined as corn with particular quality characteristics that add end-user value. Pp3 the survey found that HOC was the most commonly grown and the fastest growing type of VEC.

Producers were asked to rate the factors that influenced their decisions to plant VEC.

Those who raised VEC in 1997 rated the premiums paid for the VEC and previous

experience with VEC production as the most important factors influencing their decision to

produce VEC. Other significant positive factors are being part of the emerging market,

buyer/elevator encouragement, and seed sales encouragement (see Figure 8).

Figure 8: Producers' Reasons for Growing VEC in 1997 (U.S. Feed Grains Council,

1998) (Note: the producers were asked to rate the factors on a 1 to 5 scale with a score of 5

being very important.)

For those producers not raising VEC in 1997, lack of incentives to produce VEC,

and the fact that they were content with the current hybrids/returns they obtained from their

commodity corn were the most important reasons (see Figure 9). Other significant factors

are lack of market in the residing area, reports of poor experience from others and poor prior
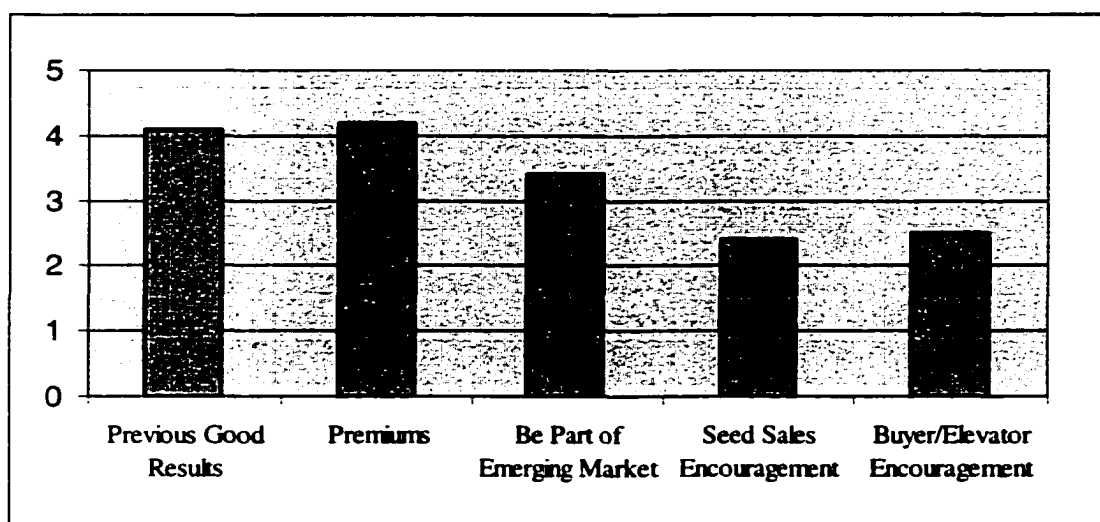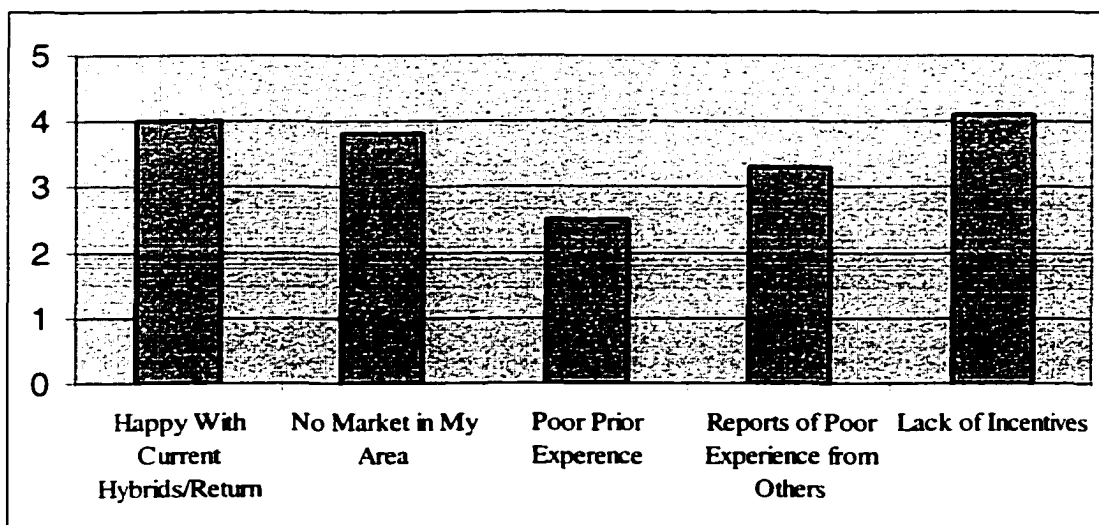
Figure 9: Producers' Reasons for Not Growing VEC in 1997 (U.S. Feed Grains

Council, 1998) (Note: the producers were asked to rate the factors on a 1 to 5 scale with a

score of 5 being very important.)

experience with VEC. Producers also mentioned that the lack of information about specialty

corn, or that they use all their corn for feed as drawbacks to VEC production.

That producers being content with growing commodity corn is one of the major

reasons they decided against growing VEC supports the theory that the biggest competitor to

VEC is commodity corn, and that our modeling of grower's acreage decisions choosing

between growing HOC and commodity corn is adequate.

Secondly, the findings clearly show that growers need adequate incentives and

information to engage in raising VEC. VEC, or specialty grains in general, require identity

preservation to preserve its added value relative to their commodity counterparts; the

number of both potential producers and buyers of these specialty grains are relatively small,

which increases marketing risk. New varieties of seeds are associated with production uncertainty. There are often additional costs such as seed premiums and segregation and handling costs. To compensate for these additional costs and the perceived increased risks in production and marketing, financial incentives must be provided to growers, and premiums are the foremost important factor in growers' decisions. Most farmers regard raising HOC as a way to increase their income. HOC must provide competitive returns to commodity corn in order for the growers to produce it.

Thirdly, information availability plays a decisive role in growers' decisions. New products are perceived to have more risk as compared with those familiar ones. Risk averse agents are reluctant to take on additional risk without compensation. More information helps to reduce the perceived risk and thus the necessary compensation to induce risk averse agents to take on the risk.

Equally important at the introductory stage of a new type of value-enhanced grains is communicating information about its added value to end-users. The added value is ultimately realized by the end-uses. End-users will not pay a premium for value unless they understand where the value comes from and how to capture it. The intrinsic characteristics of the grains are not readily verifiable by traditional grading standards, and in some cases, some practices have to be changed to capture their maximum value. For example, feed rations need to be reformulated optimally to achieve the best value of HOC. Some producers indicated that they had no interest in VEC production since they use all their corn for feed, which may indicate there is a lack of information on the value of on-farm feeding of VEC types such as HOC. On the other hand, information from seed sales representatives and elevators are conducive to VEC production.

In fact, DuPont has conducted numerous experiments on HOC. It has production and sales representatives located across the Midwest, plus nutritionists and other product development specialists, who assist companies or individuals interested in jointly developing market opportunities. These working relationships are believed to have been critical in the early growth of the HOC market. DuPont also has a website sharing information on HOC including its feed value, contracting opportunities, so that interested growers can do the contracting directly on the web. This helps to spread the information on HOC and facilitates the contracting process for both growers and elevators. Today, growers can get all kinds of information on Optimum's products and contract for production online (See Appendix 4 for Optimum contracting system).

Conceivably, end-users in the foreign countries will as well require convincing information on the value of a new product such as HOC and how to utilize the value in an optimal way before they commit to use the product. Big international importers usually work closely with multinational grain companies such as Continental Grain. Information and assistance from these exporting grain companies will help new products to gain over overseas customers and expand the products' market, especially at the beginning stage of the new variety.

Fourthly, positive externalities do exist in the popularizing process of a VEC. Previous experience with VEC production is cited as one of the two most important reasons that producers decide to get into VEC production. Although the turnover rate of VEC producers is a little bit high, some producers do stick with the practice after a good experience. Word of mouth is the oldest and sometimes most powerful tool to spread information. Poor experiences of neighbors did lead some people to stay away from VEC;

but good experiences of neighbors have the same power to lead the onlookers into the actions. Learning by doing is a self-enhancing process. Fear of uncertainty associated with a new product can be reduced and gradually managed during the producing process.

Experiences are equally enhancing for end-users too. Positive results from new products are the most concrete evidences needed to continue using the product. Customers will come to a good product repeatedly. In cases that there are set up costs associated with switching to a new product, positive first time experience will be a more powerful factor. This also implies it is easier to retain a satisfied customer than to acquire one in the first place. For HOC, an end-user doesn't have to reformulate its feed ration or acquire new (if any) processing equipment twice if it decides to continue to use HOC after it uses it successfully.

In summary, the findings are consistent with our views. Growers' decision to plant HOC is influenced by their risk attitudes, the price premium they obtain and additional costs such as seed premiums they pay relative to commodity corn, among other things. During the introduction period, services in the form of information and technical assistance are an important factor for producers to grow HOC and end-users to adopt a new product. A positive inter-period externality exists in popularizing a new product.

5.2 DuPont and Continental

The proposed model suspects that given the limited monopoly power of DuPont, the governance structure of the value chain is efficient. The choice of governance structure, in the view of transaction cost economics and property rights theory, will be determined by

safeguarding ex post opportunistic behaviors in the presence of relationship-specific

investments and by aligning ex ante incentive to make private investment.

It is difficult to test the proposal directly. The details of the agreement between the

two firms are not public information. We don't know how DuPont and Continental share the

cost and revenue exactly from marketing HOC, but we do know retrospectly that both firms

exacted great effort to expand the market of HOC and those efforts paid off in the growing

acceptance and popularity of HOC among both growers and end-users. Continental had

converted half of its international feed customers to HOC users by early 1999 (Hayenga and

Wisner, 1999).

However, we can test the proposal indirectly by examining the evolution of the

contractual relationship. If the close relationship at the beginning was determined by the

importance of both firms' private investment due to the need to create a new market for a

new product, then as the market matures over time, the importance of one or both firms'

private investment will diminish and their relationship will change correspondingly.

Continental has set up dedicated facilities to handle specialty grains including HOC, and a

significant number of its feed customers have adopted HOC. It seems its unmeasurable

efforts to provide information to convert end users and manage the merchandising are no

longer as important as before. DuPont, on the other hand, is still continuing to do research to

improve the quality of HOC by stacking more desirable genes on to it, which will improve

both the input and output traits of HOC (see Table 2). This investment in R&D is important

to further the success of HOC. Therefore, we expect DuPont's private investment to remain

important while we expect that of Continental to diminish over time. This implies DuPont

will continue to control the marketing of HOC closely but Continental will lose some of the

control. As a matter of fact, we observe that DuPont has signed on more grain firms to market HOC overseas over time. For example, on June 8, 1999, Optimum Quality Grain announced marketing agreements with AMD and ConAgra Trade Group as strategic partners to manage the growing export demand for Optimum HOC (Feedstuffs). At this stage when HOC has achieved a certain degree of acceptance among end-users, DuPont can buy services from grain firms and take the residual income itself.

We can also look at emerging products with proprietary bio-engineered quality traits (see Table 1). Monsanto is another major player in the biotechnology field besides DuPont. Monsanto has acquired a large number of seed technology patents through research and mergers and acquisitions, and it is poised to bring a series of value-enhanced grains into commercialization. On May 18, 1999, Monsanto and Cargill-a major multinational firm (which is set to acquire Continental) announced the formation of a global joint venture to create and market new products enhanced through biotechnology for the grain processing and animal feed markets (Feedstuffs, 1999). The 50-50 joint venture will combine Monsanto's capabilities in genomics, biotechnology and seeds with Cargill's global agricultural market to capture the value of innovation through seed technology. The joint venture is a profit sharing project at the beginning stage of market development of proprietary value-enhanced grains.

Other developments in the agricultural biotech sector are also consistent with the view that incentives to make private efforts play a role in shaping the governance structures. As we observed earlier in Section 2.4, the major chemical concerns' acquisitions of biotech firms started in earnest only after the first seeds with genetically modified input traits began to be commercialized, or in essence, when the bio-seeds products are produced. The benefit

of the unions between chemical and biotech firms comes mainly from the complementarity between the assets to produce chemicals and the assets to produce biotech seeds. However, those M&As did not occur at the earlier stage of the biotechnology which was characterized by intense R&D efforts. This has to do with the fact that R&D are prone to uncertainty and difficult, if not impossible to monitor, and private efforts are crucial to the success of a R&D project. Therefore, it is optimal to give ownership of the project to those whose private efforts are of vital importance. When the R&D produce patents and commercial products are being produced, the importance of the researchers' private efforts diminish, which permits an acquisition by another firm to be made without suffering two much loss from reduced private efforts.

The split between drug and agribusiness provides an example from the other way around. The creation of a so-called life science firm in the middle of 90s was based on the expectation that synergy can be achieved between agri-biotech assets and pharmaceutical assets. The synergy has turned out not to be big enough to offset the negative effect resulting from the integration. Agri-biotech and pharmaceutical businesses are both research-intensive and subject to private incentive problems. Integration has a negative impact on those private incentives. If the synergy between the two sets of assets is not large, as it seems at this stage, the life-science firms may well benefit by splitting into two separate identities. As science and technology advances, the knowledge on agri-biotech and pharmaceuticals may very well converge and these two businesses will be re-married in the future. An alternative argument for the splits is because of the controversies surrounding genetically modified organisms (GMOs). It is true that stock prices of those life science firms have been depressed and the Wall Street has put on pressure on the firms to split the business. If this argument is true,

then this behavior is a short phenomenon and we will see these two lines of businesses get back together as the controversies over GMOs are being revolved.

Conclusions

We have analyzed the governance structure of the value-adding partnership in commercializing a proprietary value-enhanced grain-HOC, and in particular, the alliance formed between the technology provider-DuPont and a grain exporter-Continental. We found that at the early stage, DuPont's biotechnology and Continental's grain export assets are complementary to create a market for HOC, and relationship-specific private investments are important, which may determine the governance structure of the cooperation between the two firms. It is optimal to give each a partial ownership of complementary assets when both of their private efforts are essential; and when only one party contributes important private efforts, this party should have sole ownership of the project. The relative importance of these private efforts will change over time due to the evolution of technology and competition, so will the governance structure. This may shed some light on the commercialization of other proprietary value-enhanced grains. We will see more coordination at the beginning of the market creation, and less when a market is created and the volume of production expands to a certain scale.

APPENDIX 1

RECENT RESTRUCTURING ACTIVITIES

Consolidation between chemicals, biotech and seed firms: Monsanto has been the most aggressive in mergers and acquisitions. In 1996 and 1997, it went on a buying spree which ended with acquiring 16 biotech or seed firms. Its large deals include the following:

- It acquired Asgrow Agronomics which had a 5% worldwide share of the corn seed market and an 18% worldwide soybean seed market in September, 1996.

- It purchased Holden's Foundation Seeds Inc. (a leading foundation seed company) in January 1997.

- It finalized an agreement to buy Calgene in April 1997. Calgene is an agriculture biotechnology company that had done significant research in oils, fresh produce and cotton. The two firms signed an oilseed collaboration agreement in June 1996, and Monsanto gained the control of the firm by increasing its equity ownership interest from 49.9 to 54.6%.

- It completed the purchase of DeKalb Genetics, then the 2nd largest U.S. seed firm, in December 1998. When Monsanto announced to buy out DeKalb in May 1998, it had previously acquired 40% of the equity stake in DeKalb.

- It announced to buy the international seed business from Cargill in June 1998.

    DuPont is another player in the sector that aggressively seeks to transform itself into a life science company that pursues a synergy among biotech, drug, nutrition and agriculture. Besides some small acquisitions and extensive alliances, its most significant acquisition is Pioneer Hibred International.

- DuPont and Pioneer signed an agreement that DuPont would buy the 80% stake in Pioneer that it did not already own in March 1999. Pioneer became a wholly owned subsidiary of DuPont subesequently. The acquisition followed a close relationship between the two firms dating back to 1997. In 1997, they entered a three-part strategic alliance: A research partnership which included a broad research collaboration, a joint venture Optimum Quality Grains, L.L.C., and a 20% equity investment by DuPont in Pioneer.

    Other acquisitions in this sector include:

- Dow Agrosciences announced its intention to acquire Mycogen in October 1998. Mycogen had 4% market share in corn seed market. Dow Agrosciences had 69% of the equity in Mycogen before that.

- Dow Agrosciences also acquired part of Illinois Foundation Seeds which provides foundation seeds for 11% of branded seed corn sales by other companies.

- AgrEvo, a Berlin-based joint venture between Hoechst and Schering, announced they planned to acquire Cargill's domestic seed business in 1998, the deal however, has never been completed due to concerns about the marketability of biotech based products.

- Cargill, which didn't have access to biotechnology and the new genetic products produced by it, sold its international seed businesses to Monsanto.

Split between drug and agribusiness: After the flurry of mergers between drug and agricultural biotech firms to create a "life-science" conglomerate in earlier years, there is now a trend going in the reverse direction-some firms are splitting their pharmaceutical and agribusiness.

- Novartis and AstraZeneca agreed to spin off and merge Novartis Crop Protection and Seeds business and Zeneca Agrochemicals to create the world's first dedicated agribusiness company in December 1999. Novartis will focus on its healthcare - pharmaceuticals business. AstraZeneca was created by the take-over of Zeneca, the UK life science leader, by Astra, a pharmaceutical company based in the Neverthlands. Novartis was the combination of Sandoz and Ciba Geigy.The new firm- to be named Syngenta-would be No. 1 in Crop protection and No. 3 in seeds with $7.9 billion in combined 1998 sales. They have complementary product portfolios and strong global sales and marketing culture. It will have a strong innovation platform in chemistry and plant technology.

- On March 21, 2000, American Home Products (AHP), the No.5 U.S. drug-maker, announced that it was exiting the agriculture business to focus on its core businesses of pharmaceuticals and consumer products. It will sell its Cyanamid crop-protection unit to the German chemicals firm BASF AG. AHP acquired Cyanamid in 1994.

Alliances between biotech firms and grain companies: Several biotech firms have formed alliances with grain companies to create markets for value-enhanced grains.

- DuPont and Continental Grain formed an alliance to market HOC in early 1996. It later signed agreements with ADM and ConAgra to market HOC in 1998.

- Novartis announced an agreement tc form a joint venture with Land O'Lakes to produce specialty corn products in 1998.

- Monsanto and Cargill formed a joint venture to arrange production and market value-enhanced grain 1998.

    Consolidation of the grain companies: Joint ventures and acquisitions are common among grain companies as well.

- In November 1998, Cargill announced that it intended to acquire Continental Grain's grain storage, transportation, export and trading operations in North America, Europe, Latin America and Asia with customers in over 100 countries. The two firms are the top grain exporters in the U.S..

- In March 1999, two of the largest U.S. farm cooperatives, Farmland Industries Inc. and Cenex Harvest States, announced plans to merge portions of their grain businesses.

(Note: the information above is collected from www.quote.yahoo and *Feedstuffs*.)

APPENDIX 2

PROOFS

A: Section 4.2.2-CARA Utility Function

A CARA Utility Function and Normality $\Rightarrow E(u) \propto \overline{w} - \frac{1}{2}\lambda\sigma_w^2$

A CARA utility function is represented by: $u = a - be^{-\lambda w}$.

$$w \sim N(\overline{w}, \sigma_w^2) \Rightarrow f(w/\overline{w}, \sigma_w^2) = \frac{1}{\sqrt{2\pi}\sigma_w} e^{-\frac{(w-\overline{w})^2}{2\sigma_w^2}}$$

$$E(e^{-\lambda w}) = \int e^{-\lambda w} \frac{1}{\sqrt{2\pi}\sigma_w} e^{-\frac{(w-\overline{w})^2}{2\sigma_w^2}} dw$$

$$= \int \frac{1}{\sqrt{2\pi}\sigma_w} e^{-\frac{(w-\overline{w})^2 + 2\lambda\sigma_w^2 w}{2\sigma_w^2}} dw$$

$$= e^{-\lambda\overline{w}+\frac{1}{2}\lambda^2\sigma_w^2} \int \frac{1}{\sqrt{2\pi}\sigma_w} e^{-\frac{(w-\overline{w}+\lambda\sigma_w^2)^2}{2\sigma_w^2}} dw$$

$$= e^{-\lambda\overline{w}+\frac{1}{2}\lambda^2\sigma_w^2} \qquad (\int \frac{1}{\sqrt{2\pi}\sigma_w} e^{-\frac{(w-\overline{w}+\lambda\sigma_w^2)^2}{2\sigma_w^2}} dw = 1 \text{ since it is the}$$

cumulative function of $w - \lambda\sigma_w^2 \sim N(\overline{w} - \lambda\sigma_w^2, \sigma_w^2)$)

$\Rightarrow E(e^{-\lambda w}) \propto -\lambda\overline{w} + \frac{1}{2}\lambda^2\sigma_w^2 \qquad (e^x$ is an increasing function of x)

$\Rightarrow E(e^{-\lambda w}) \propto -\overline{w} + \frac{1}{2}\lambda\sigma_w^2 \qquad (\lambda > 0)$

$\Rightarrow E(-e^{-\lambda w}) \propto \overline{w} - \frac{1}{2}\lambda\sigma_w^2$

$\Rightarrow E(u) \propto \overline{w} - \frac{1}{2}\lambda\sigma_w^2 \qquad (E(u) \propto E(-e^{-\lambda w}))$

$\Rightarrow \max_w E(u) \Leftrightarrow \max_w (\overline{w} - \frac{1}{2}\lambda\sigma_w^2)$

B: A Proof of Results in 4.2.2

$$\frac{\partial A2}{\partial \gamma} = \frac{(\bar{y} + \bar{\varepsilon} - \lambda pA\sigma_y^2)\lambda[\gamma^2\sigma_y^2 + (p+\gamma)^2] - 2[\gamma\bar{y} + (p+\gamma)\bar{\varepsilon} - s - \lambda pA\gamma\sigma_y^2]\lambda[\gamma\sigma_y^2 + (p+\gamma)\sigma_\varepsilon^2]}{\lambda^2[\gamma^2\sigma_y^2 + (p+\gamma)^2\sigma_\varepsilon^2]^2}$$

(A2-1)

The necessary and sufficient condition for $\dfrac{\partial A2}{\partial \gamma} > 0$ is:

$$(\bar{y} + \bar{\varepsilon} - \lambda pA\sigma_y^2)[\gamma^2\sigma_y^2 + (p+\gamma)^2\sigma_\varepsilon^2] - 2[\gamma\bar{y} + (p+\gamma)\bar{\varepsilon} - s - \lambda pA\gamma\sigma_y^2][\gamma\sigma_y^2 + (p+\gamma)\sigma_\varepsilon^2] > 0 \text{ (A2-2)}$$

Let $b \equiv -\gamma^2\sigma_y^2 + (p^2 - \gamma^2)\sigma_\varepsilon^2$, then (A2-2) can be written as:

$$(\bar{y} + \bar{\varepsilon})b - \frac{p\bar{\varepsilon} - s}{\gamma}.2[\gamma^2\sigma_y^2 + \gamma(p+\gamma)\sigma_\varepsilon^2] > \lambda pA\sigma_y^2 b \text{ (A2-3)}$$

Case (1): $b > 0$, then (A2-3) becomes (A2-4):

$$(\bar{y} + \bar{\varepsilon}) - \frac{p\bar{\varepsilon} - s}{\gamma}.2[\gamma^2\sigma_y^2 + \gamma(p+\gamma)\sigma_\varepsilon^2]\frac{1}{b} > \lambda pA\sigma_y^2 \text{ (A2-4)}$$

With $A2 > 0$ implying $(\bar{y} + \bar{\varepsilon}) - \dfrac{p\bar{\varepsilon} - s}{\gamma} > \lambda pA\sigma_y^2$ (A2-5),

$$2[\gamma^2\sigma_y^2 + \gamma(p+\gamma)\sigma_\varepsilon^2]\frac{1}{b} \geq 1 \text{ will be a sufficient condition for (A2-4) to hold.}$$

Case (2), $b < 0$, then (A2-3) becomes (A2-6):

$$(\bar{y} + \bar{\varepsilon}) - \frac{p\bar{\varepsilon} - s}{\gamma}.2[\gamma^2\sigma_y^2 + \gamma(p+\gamma)\sigma_\varepsilon^2]\frac{1}{b} < \lambda pA\sigma_y^2 \text{ (A2-6)}$$

It is possible that (8) holds for $A2 > 0$ because (A2-6) and (A2-5) may coexist due to

$$(\bar{y} + \bar{\varepsilon}) - \frac{p\bar{\varepsilon} - s}{\gamma}.2[\gamma^2\sigma_y^2 + \gamma(p+\gamma)\sigma_\varepsilon^2]\frac{1}{b} < (\bar{y} + \bar{\varepsilon}) - \frac{p\bar{\varepsilon} - s}{\gamma}.$$

C: A Proof of the Sign of $\theta_{\gamma s}$ in Section 4.4.1

Let θ be the total surplus to Dupont and Continental as in equation 4, that is

$$\theta = TS(\gamma, s) = E[r(s)A2(\gamma, s) + (p + \beta)Y - (p + \gamma)Y - F - VC(Y)] \qquad \text{(A2-7)}.$$

The first order condition for maximizing θ with respect to the price premium (γ) is given in equation 5 from Chapter 4. We repeat it here for convenience.

$$\left[r(s) + (\beta - \gamma)(\bar{y} + \bar{\varepsilon})\right]\frac{\partial A2}{\partial \gamma} - A2(\gamma, s)(\bar{y} + \bar{\varepsilon}) - E\left[\frac{\partial VC}{\partial Y}\frac{\partial A2}{\partial \gamma}(y + \varepsilon)\right] = 0 \qquad (5).$$

Equation 5 can be rearranged to give

$$\left\{r(s) + (\beta - \gamma)(\bar{y} + \bar{\varepsilon}) - E\left[\frac{\partial VC}{\partial Y}(y + \varepsilon)\right]\right\}\frac{\partial A2}{\partial \gamma} = A2(\gamma, s)(\bar{y} + \bar{\varepsilon}) \qquad (A2\text{-}8).$$

The derivative of θ with respect to γ is the same as that in (5), specifically

$$\theta_\gamma = \left[r(s) + (\beta - \gamma)(\bar{y} + \bar{\varepsilon})\right]\frac{\partial A2}{\partial \gamma} - A2(\gamma, s)(\bar{y} + \bar{\varepsilon}) - E\left[\frac{\partial VC}{\partial Y}\frac{\partial A2}{\partial \gamma}(y + \varepsilon)\right] \qquad (A2\text{-}9).$$

Differentiating A2-9 with respect to s will yield

$$
\begin{aligned}
\theta_{\gamma s} &= \left[r(s) + (\beta - \gamma)(\bar{y} + \bar{\varepsilon})\right]\frac{\partial^2 A2}{\partial s \partial \gamma} - (\bar{y} + \bar{\varepsilon})\frac{\partial A2}{\partial s} + \frac{\partial A2}{\partial \gamma}\frac{\partial r(s)}{\partial s} \\
&\quad - E\left[\frac{\partial VC}{\partial Y}\frac{\partial^2 A2}{\partial s \partial \gamma}(y + \varepsilon)\right] - E\left[\frac{\partial^2 VC}{\partial Y^2}\frac{\partial A2}{\partial \gamma}(y + \varepsilon)\right] \\
&= \left\{r(s) + (\beta - \gamma)(\bar{y} + \bar{\varepsilon}) - E\left[\frac{\partial VC}{\partial Y}(y + \varepsilon)\right]\right\}\frac{\partial^2 A2}{\partial s \partial \gamma} \\
&\quad - (\bar{y} + \bar{\varepsilon})\frac{\partial A2}{\partial s} + \frac{\partial A2}{\partial \gamma}\frac{\partial r(s)}{\partial s} - E\left[\frac{\partial^2 VC}{\partial Y^2}\frac{\partial A2}{\partial \gamma}(y + \varepsilon)\right]
\end{aligned}
\qquad (A2\text{-}10)
$$

We can sign the coefficient of $\dfrac{\partial^2 A2}{\partial s \partial \gamma}$ in A2-10 using equation A2-8. Because the right hand side of

A2-8 is positive and we assume $\dfrac{\partial A2}{\partial \gamma} > 0$, the coefficient of $\dfrac{\partial A2}{\partial \gamma}$ must be greater than zero and

this coefficient is the same as the coefficient of $\dfrac{\partial^2 A2}{\partial s \partial \gamma}$ in A2-10. This then implies that

$$\left\{r(s) + (\beta - \gamma)(\bar{y} + \bar{\varepsilon}) - E\left[\frac{\partial VC}{\partial Y}(y + \varepsilon)\right]\right\} > 0 \qquad (A2\text{-}11).$$

We can also sign $\dfrac{\partial^2 A2}{\partial s \partial \gamma}$ by computing the relevant derivatives. First rewrite equation 3 from

Chapter 4 as

$$A2 = \frac{(p+\gamma)\overline{\varepsilon} - s - \lambda pA\gamma\sigma_y^2 + \gamma\overline{y}}{\lambda\left[\gamma^2\sigma_y^2 + (p+\gamma)^2\sigma_\varepsilon^2\right]} \quad (3)$$

Now take the derivative of 3 with respect to s as follows

$$\frac{\partial A2}{\partial s} = \frac{-1}{\lambda\left[\gamma^2\sigma_y^2 + (p+\gamma)^2\sigma_\varepsilon^2\right]} < 0 \quad (A2\text{-}12).$$

This derivative is negative because $\lambda > 0$ and all other terms are squared. Differentiating again we obtain

$$\frac{\partial^2 A2}{\partial s \partial \gamma} = \left\{\lambda\left[\gamma^2\sigma_y^2 + (p+\gamma)^2\sigma_\varepsilon^2\right]\right\}^{-2}\lambda\left[2\gamma\sigma_y^2 + 2(p+\gamma)\sigma_\varepsilon^2\right] > 0 \quad (A2\text{-}13).$$

Equation A2-13 will be positive because $\lambda > 0$, $\gamma > 0$, p > 0, and all other terms are squared. This implies the entire first term in A2-10 is positive. The second term in A2-10 is positive because we

have shown in equation A2-12 that $\dfrac{\partial A2}{\partial s} < 0$, that is

$$-(\overline{y}+\overline{\varepsilon})\frac{\partial A2}{\partial s} > 0 \quad (A2\text{-}14).$$

The third term is positive because of our assumption in Chapter 4 that $\dfrac{\partial A2}{\partial \gamma} > 0$ and $\dfrac{\partial r(s)}{\partial s}$. We

than have

$$\frac{\partial A2}{\partial \gamma}\frac{\partial r(s)}{\partial s} > 0 \quad (A2\text{-}15).$$

The first three terms in A2-10 are thus positive and the overall sign of θ_{ys} will depend on the sign

and magnitude of $-E\left[\dfrac{\partial^2 VC}{\partial Y^2}\dfrac{\partial A2}{\partial \gamma}(y+\varepsilon)\right]$. If there are increasing returns to size in the handling of

grain $\left(\dfrac{\partial^2 VC}{\partial Y^2} < 0\right)$, then given that $\dfrac{\partial A2}{\partial \gamma} > 0$, this term will also be positive and the overall sign of

θ_{ys} will be positive. It there are decreasing returns to size in the handling of grain $\left(\dfrac{\partial^2 VC}{\partial Y^2} > 0\right)$,

then given that $\dfrac{\partial A2}{\partial \gamma} > 0$, then this term will be negative and could cause the overall derivative to

be negative. Increasing returns to scale may well be the most reasonable assumption during the early stages of the commercialization of HOC. Whether decreasing returns at higher output levels dominate in the later stages is an open empirical question. Summarizing,

If $\dfrac{\partial^2 VC}{\partial Y^2} \le 0$, then $-E\left[\dfrac{\partial^2 VC}{\partial Y^2}\dfrac{\partial A2}{\partial \gamma}(y+\varepsilon)\right] \ge 0$, and $\theta_{ys} > 0$.

If $\dfrac{\partial^2 VC}{\partial Y^2} > 0$, then $-E\left[\dfrac{\partial^2 VC}{\partial Y^2}\dfrac{\partial A2}{\partial \gamma}(y+\varepsilon)\right] < 0$, and the sign of θ_{ys} is ambiguous.

D: A Proof of the Result in 4.4.2

Let $\varphi = TS(i, I) = B(i, I) - F - c(i) - C(I)$, then (12) becomes:

$$i : \varphi_i = 0$$
$$I : \varphi_I = 0 \qquad (12')$$

(i^*, I^*) is the optimal solution to (12').

The second order condition is: $H = \begin{vmatrix} \varphi_{ii} & \varphi_{iI} \\ \varphi_{Ii} & \varphi_{II} \end{vmatrix}$ is negative definite, which gives:

$$\varphi_{ii} < 0, \varphi_{II} < 0, \varphi_{ii}\varphi_{II} - \varphi_{iI}\varphi_{Ii} > 0 \Rightarrow \left|\dfrac{\varphi_{II}}{\varphi_{Ii}}\right| > \left|\dfrac{\varphi_{iI}}{\varphi_{ii}}\right|$$

Using (12') and the Implicit Function Theorem, we will get:

$$\dfrac{di}{dI}\bigg|_{\varphi_i=0} = -\dfrac{\varphi_{iI}}{\varphi_{ii}}, \text{ and } \dfrac{di}{dI}\bigg|_{\varphi_I=0} = -\dfrac{\varphi_{II}}{\varphi_{Ii}}$$

Evaluating (12') at $(\tilde{i}, \tilde{I})$ using $\dfrac{\partial B(i, I)}{\partial i} > 0, \dfrac{\partial B(i, I)}{\partial I} > 0$ gives $\varphi_i\big|_{(\tilde{i},\tilde{I})} < 0$ and $\varphi_I\big|_{(\tilde{i},\tilde{I})} < 0$ when

$B_{iI} < 0$; $\varphi_i\big|_{(\tilde{i},\tilde{I})} > 0$ and $\varphi_I\big|_{(\tilde{i},\tilde{I})} > 0$ when $B_{iI} > 0$. We can't sign B_{iI} in general.

Using the results obtained above, we can draw the graphs in Figure 5-A and Figure 5-B.

APPENDIX 3

VALUE OF HOC

A number of tests and experiments have been conducted to determine the intrinsic value of HOC by researchers in various firms and organizations. Almost all of them conclude that HOC contains a much higher oil level than conventional corn, oil content is increased at the expense of starch. A study by the U.S. Feed Grain Council in 1998 shows HOC has 7.2% oil compared with 4.4% oil in commodity corn, and starch of 64.8% to 70.6% (see Table A3.1). The amount of energy available for metabolism from corn starch is 4,040 kcal/kg and of corn oil 7,350 kcal/kg. Thus, for each one-percent unit of corn starch replaced by corn oil, there should be a net increase of 33.3 kcal/kg of metabolizable energy. More metabolizable energy means greater feed value. In addition, the crude protein level in HOC tends to be higher than commodity corn, so the concentration of key amino acids in HOC should be higher (see table A3.1). Preliminary data obtained from pig experiments suggests that the amino acids in HOC are somewhat more digestible than those found in traditional yellow dent corn.

Reports evaluating the nutritive value of HOC for poultry, swine and cow (Yu, 1998) find several potential advantages of using HOC. The most obvious one is reducing feed costs by substituting HOC for more expensive feed supplements such as soybean meal, fat and amino acid. It provides a consistent source of metabolizable energy and amino acid with consistent quality, and reduces the risk associated with the usage of added fats of unknown or poor quality. The latter is especially valuable in tropical countries where handling fat is not only greasy but also costly. In countries where fat is prohibited to be used as animal feed by religion, HOC fares even better. It is even more cost effective for smaller feeders who buy fat at a higher price and mix fat with other feed ingredients at a higher cost than big livestock producers. HOC also provides more choices for feed formulation (Crum and Stilborn, 1997).

Less obviously, HOC has some additional benefits such as much lower dust levels in feeding operations, improved palatability, better uniformity in mixing, and easier handling of feeds. These attributes add value but are often situation dependent, and are more difficult to quantify in direct financial terms for a general situation. (see http://www.ncga.com/02profits/HighOil/premval2.html National Corn Growers Association's website)

Table A3.1 Average Nutrient Composition of Conventional Corn and HOC

Nutrient	HOC	Commodity corn
Oil, % (d.b.)	7.2	4.4
Protein, % (d.b.)	9.9	9.4
Starch, % (d.b.)	64.8	70.6
Fiber, % (d.b.)	2.9	2.3
Lysine, %	0.28	0.28
Methionine, %	0.20	0.17
Threonine, %	0.31	0.30
Tryptophan, %	0.07	0.06

Source: 1997-1998 *Value-enhanced Corn Quality Report* by U.S. Feed Grain Council, pp5

APPENDIX 4

THE OPTIMUM CONTRACTING SYSTEM

DuPont has utilized internet to provide information and do contracting from the early stage of HOC commercialization. The website started as DuPont Quality Grains and posted detailed information on the feed value of HOC and grower contracting. The first export program was the one with Continental Grain. Growers can log onto the website and do the contracting via an internet system called OSCAR. Now, the website has evolved into the current one held by Optimum Quality Grains, L.L.C. (Optimum) at www.itsoptimum.com. Optimum worked with both overseas livestock producers and domestic growers/feeders to help create a market for HOC. It has been sponsoring field trials by independent researchers to substantiate and refine the advantages of HOC in feed nutrition. Those trial results are readily available at its website. The contracting programs have expanded to include both export and domestic programs on not only HOC but also other value-enhanced grains such as High Oleic HOC and STS soybeans. The electronic system brings the growers and elevators/feeders/processors together, and both Optimum and its grain partners can easily monitor the contracting progress. However, Optimum's role is different with domestic and export contracts. For domestic contracts, Optimum only serves as an intermediary that connects the growers and elevators/feeders/processors, and it is not a legal party to the domestic production contracts. For export contracts, Optimum is a legal party to the contracts and stands behind them.

All the export contracts are fairly standardized (see a sample contract in Appendix 4). The contract is for a quantity of acres; a grower is required to buy seeds from a list of companies that have licensed HOC technology from DuPont. The product must meet physical quality specifications. Pricing is based on the Elevator cash price for U.S. No.2 yellow corn plus a fixed premium based upon the oil content of the grain. The higher the oil content, the higher the premium. The contracts grant Optimum and/or its appointed agents free and easy access to the fields to inspect, evaluate and monitor the progress and condition of the crop.

The Optimum electronic contracting system, as other e-commerce tools, has greatly facilitated the information dissemination and managing the business. It makes it much easier for Optimum to monitor and coordinate the activities of the growers and its grain partners. Growers gain easy access to useful knowledge and assistance from Optimum. The participating grain firms and processors can use the system to monitor and plan its activities in an up-to-date fashion. This system

reduces variable transaction costs for all participants, and is an investment that benefits all. The investor, Optimum (or DuPont) stands to benefit most from this system.

APPENDIX 5

A SAMPLE OF HOC GROWER CONTRACT

Contract Number: **#CONTRACT ID**
Originator: **OriginFName OriginLName OriginatorPhone OriginatorCompany**
Program: **Optimum Quality Grains, L.L.C. /Consolidated Grain and Barge**

Optimum Quality Grains, L.L.C.
2000 EXPORT MARKETING AGREEMENT
FOR OPTIMUM® HIGH OIL CORN
Buyer's call

THIS AGREEMENT is made **DATE** between **GrowerDisplayName** (hereinafter "GROWER") and Optimum Quality Grains, L.L.C. (hereinafter "OPTIMUM"), and relates to the production and delivery of OPTIMUM® high-oil corn grain (hereinafter "OPTIMUM GRAIN") from certain high-oil hybrid seed corn or TC BLEND® seed corn (hereinafter collectively "HOC SEED"). GROWER and OPTIMUM are experienced and knowledgeable in the cultivation of corn and business transactions involving corn.

1. GENERAL TERMS
a. GROWER shall produce and deliver an "Identity Preserved" crop from HOC SEED purchased from seed companies that are on the 2000 OPTIMUM HOC SEED company list (see Attachment A).
b. GROWER shall produce the highest quality grain possible and meet the specifications in Article 3. GROWER shall take all measures to prevent contaminants during growing and handling OPTIMUM GRAIN, and may not blend with non-OPTIMUM GRAIN.
c. GROWER agrees to sell and deliver 100% of the contracted production of OPTIMUM GRAIN to ELEVATORNAME(hereinafter "ELEVATOR"). All marketing activities and GROWER payments will be handled by the ELEVATOR or a replacement elevator or grain merchandiser designated by OPTIMUM and shall be subject to a separate grain purchase agreement between GROWER and ELEVATOR.
d. GROWER agrees to plant and grow **TOTALQuantity** acres of OPTIMUM GRAIN. Pricing and GROWER compensation for the OPTIMUM GRAIN are in Article 4. If GROWER is unable to perform all terms of this Agreement for any reason, GROWER agrees to promptly notify both OPTIMUM (1-888-707-7648) and ELEVATOR.
e. GROWER will purchase
SEEDCOMPANIES
* Seed company name is required for the Agreement to be valid. If GROWER purchases seed from seed company(s) other than as designated above, whether due to unavailability of seed or GROWER's choice, or is unable to purchase seed in order to perform this Agreement, GROWER agrees to promptly notify OPTIMUM by calling 1-888-707-7648. Neither OPTIMUM nor any seed company designated above guarantees seed availability or sale.

f. GROWER is to request and read the specifications and the complete Purchase Agreement and the Limitation of Warranty and Liability associated with all HOC SEED purchased for use under this Agreement. GROWER agrees to abide by the terms and conditions of the Purchase Agreement.

g. GROWER grants OPTIMUM and/or its appointed agents free and easy access to the fields to inspect, evaluate and monitor the progress and condition of the crop.

h. GROWER agrees not to use any grain storage chemicals - either applied directly to the OPTIMUM GRAIN or to the storage structure in which the OPTIMUM GRAIN is to be stored, and GROWER further agrees to certify compliance with this provision.

i. To minimize risk of cross-pollination, GROWER agrees that he will not plant HOC SEED within 50 feet of any transgenic or GMO (genetically modified organism) corn; and GROWER further agrees to certify his compliance with this provision.

j. For purposes of this agreement, "transgenic or GMO (genetically modified organism) corn" refers to a crop produced from seed containing DNA from another organism; e.g., Bt-derived insect resistance, Roundup Ready ® or Liberty Link ® herbicide resistance, etc.

2. DELIVERY AND STORAGE

a. Delivery is BUYER'S CALL. GROWER shall deliver the dried OPTIMUM GRAIN to ELEVATOR with transportation costs paid by the GROWER. For OPTIMUM GRAIN redirected by OPTIMUM to another facility, that receiving location on behalf of OPTIMUM will pay additional transportation costs.

b. The delivery period(s) shall be the following:

DeliveryWindows

The ELEVATOR will provide a minimum of one week pre-advice of the requested delivery date.

c. GROWER must get written permission from ELEVATOR to change delivery period. In the event of a delay in the designated delivery period caused by ELEVATOR or OPTIMUM, GROWER will be compensated on all priced bushels at a rate of $0.0007 cent per bushel per day from the last day of the delivery period indicated above until the OPTIMUM GRAIN is called. All OPTIMUM GRAIN must be delivered no later than August 31, 2001.

d. GROWER shall not allow or cause any liens or security interests to be placed on the OPTIMUM GRAIN that would prevent the unencumbered delivery of the High Oil Corn grain or that conveys ownership of the crop to anyone other than the GROWER, the ELEVATOR or OPTIMUM.

3. PHYSICAL QUALITY SPECIFICATIONS

OPTIMUM GRAIN shall meet the following specifications, or it shall be subject to the ELEVATOR'S discount schedule or rejection.

a. The specifications for OPTIMUM GRAIN shall be:

Moisture	15.0% Maximum
Test Weight	54.0 lbs. Minimum
BCFM	2.0% Maximum
Damage	3.0% Maximum
Aflatoxin	< 20 ppb
Odor	Cool, sweet and of merchantable quality.
Contamination	For identity preserved
Blending	handling, no corn grain from other types allowed and meets all U.S. No. 2 Yellow Corn quality standards not listed above. OPTIMUM GRAIN blended with any non-OPTIMUM GRAIN will not be accepted.

b. If the moisture exceeds the above limits or has test weight less than the above minimum, the OPTIMUM GRAIN will be subject to rejection or discounts, and drying charges set forth by the receiving ELEVATOR. The following discounts apply for BCFM and damage.

BCFM DISCOUNTS	DAMAGE DISCOUNTS
$0.02 Each 1.0% From 2.1-4.0%	$0.01 Each 1.0% From 3.1-5.0%

c. OPTIMUM GRAIN delivered under this Agreement shall be of merchantable quality, unadulterated and unrestricted from movement in interstate commerce within the meaning of the Federal Food, Drug, and Cosmetic Act, Environmental Protection Agency Tolerances, the United StatesGrain Standards Act and applicable state law.

d. Any individual load of OPTIMUM GRAIN with greater than 20 PPB Aflatoxin, not cool and sweet, not of merchantable quality or rejected as a result of not meeting any of the specifications in this Agreement shall not be accepted and no premium will be paid for oil content. Such load(s) shall be subject to rejection or purchased as yellow corn at the sole discretion of the ELEVATOR. Such load(s) shall not be commingled with other OPTIMUM GRAIN produced by GROWER.

e. The ELEVATOR'S weights and grades shall govern with the exception that GROWER has the right to appeal any grading by having the elevator submit a sample to the Federal Grain Inspection Service (FGIS), at GROWER'S expense, for an official grade.

f. GROWER will provide a representative sample of GROWER'S OPTIMUM GRAIN before delivery if requested by OPTIMUM. OPTiMUM will provide sample bags and sample shipping instructions to the GROWER. OPTIMUM or their representative shall have the right to sample bins of OPTIMUM GRAIN prior to delivery.

4. PRICING AND GROWER COMPENSATION

a. The ELEVATOR or OPTIMUM will compensate the GROWER for performing this Agreement. The compensation for a load of delivered, dried OPTIMUM GRAIN shall be the ELEVATOR cash price for U.S. No. 2 Yellow Corn, basis the export market for commodity corn on day of delivery (if not priced earlier with ELEVATOR), less any discounts, plus a premium based upon the oil content (see the SCALE below) times the total number of net bushels of the OPTIMUM GRAIN delivered. GROWER acknowledges that depending upon market conditions, the pricing of OPTIMUM GRAIN may be higher or lower than the local price of generic yellow corn. The GROWER agrees to accept this export price as the final determination in the settlement of the OPTIMUM GRAIN.

PREMIUM SCALE

Less than 6.0% oil*, $0.00 per bushel

6.0% oil $.05 per bu.	7.0% oil $.15 per bu.
6.1% oil $.06 per bu.	7.1% oil $.16 per bu.
6.2% oil $.07 per bu.	7.2% oil $.17 per bu.
6.3% oil $.08 per bu.	7.3% oil $.18 per bu.
6.4% oil $.09 per bu.	7.4% oil $.19 per bu.
6.5% oil $.10 per bu.	7.5% oil $.20 per bu.
6.6% oil $.11 per bu.	7.6% oil $.21 per bu.
6.7% oil $.12 per bu.	7.7% oil $.22 per bu.
6.8% oil $.13 per bu.	7.8% oil $.23 per bu.
6.9% oil $.14 per bu.	7.9% oil $.24 per bu.

8.0% oil or greater $.25 per bu.

*All oil contents are expressed on a zero moisture basis

b. In addition, DUPONT is offering a GROWER profit incentive of $15 per bag on each bag of TC BLEND® seed you buy from participating OPTIMUM HOC seed companies. To qualify for the 2000 DuPont Bonus Program, grower must utilize qualifying DuPont Crop Protection Products on 50% or more of their total corn acres. For additional information on this incentive, call 1-888-6-DUPONT.

c. Oil content of OPTIMUM GRAIN shall be determined by the ELEVATOR, utilizing a grain analyzer with an OPTIMUM approved calibration for OPTIMUM GRAIN, on a representative sample drawn from each load. Details of the sampling and measurement procedure may be obtained from the ELEVATOR.

d. In the event of a disagreement or dispute related to oil content, the GROWER may request that such sample be re-analyzed. The oil content for determining the premium due shall be the average value of the two sample measurements. If the GROWER requests a third party analysis, then GROWER has the right, at GROWER'S expense, to have ELEVATOR submit the same sample to the Federal Grain Inspection Service (FGIS). The parties agree that the oil content as determined by FGIS shall be used to determine the premium for the OPTIMUM GRAIN.

e. If a grain analyzer with an OPTIMUM approved calibration for OPTIMUM GRAIN is not available at the ELEVATOR when the GROWER delivers the OPTIMUM GRAIN, then GROWER shall allow ELEVATOR reasonable time to obtain oil analysis.

5. INDEPENDENT CONTRACTOR

GROWER is, for purposes of this Agreement, an independent contractor and nothing contained in this Agreement shall make GROWER an employee or agent of OPTIMUM or ELEVATOR or authorize him/her to act on behalf of OPTIMUM or ELEVATOR. GROWER shall indemnify, defend and hold OPTIMUM or ELEVATOR harmless from all claims in any way connected directly or indirectly with GROWER'S operations pursuant to this Agreement.

6. DISCLAIMER OF WARRANTY AND LIMITATION OF DAMAGES

Actual total oil content of the OPTIMUM GRAIN produced by the GROWER will vary and is influenced by factors such as variety selected, date of planting, occurrence of disease, insects including corn rootworm beetle, accumulated growing degree days during the growing season, contaminating pollination by non-high oil corn varieties, failure to follow the recommended method of use, and the breakdown of male sterility of the hybrid seed corn incorporated in the TC BLEND® seed under adverse weather conditions, all of which are beyond the control of OPTIMUM. **OPTIMUM MAKES NO WARRANTIES OF MERCHANTABILITY OR FITNESS FOR A PARTICULAR PURPOSE OR ANY OTHER EXPRESS OR IMPLIED WARRANTY.**

NO CLAIM OF ANY KIND, WHETHER OR NOT BASED ON NEGLIGENCE, SHALL BE GREATER IN AMOUNT THAN THE VALUE OF COMMERCIAL SEED IN A QUANTITY COMPARABLE TO THAT QUANTITY OF SEED SUBJECT TO THIS AGREEMENT. NEITHER PARTY SHALL BE LIABLE FOR SPECIAL, CONSEQUENTIAL, PUNITIVE, EXEMPLARY, OR INDIRECT DAMAGES AND THE MEASURE OF DAMAGES SHALL BE WITHOUT REGARD TO THE CAUSE RELATIVE THERETO AND WHETHER OR NOT CAUSED BY OR RESULTING FROM THE NEGLIGENCE OF SUCH PARTY.

7. MISCELLANEOUS

a. This Agreement constitutes the complete and exclusive statement of the understanding between the parties and supersedes all prior and collateral representations. Any alteration, modification, or amendment of the Agreement shall not be valid and binding unless in writing and signed by both parties. This Agreement shall bind parties hereto, their heirs, administrators, executors, successors, and assigns.

b. This Agreement shall be governed by Iowa law, without regard to conflict of law principles. OPTIMUM and GROWER agree that all disputes and differences arising between OPTIMUM and GROWER out of or relating in any way to this Agreement, the construction, meaning and operation, or effect of this Agreement, or breach thereof, shall be settled by arbitration in accordance with the rules and regulations of the National Grain and Feed Association pursuant to such Association's

grain arbitration rules. OPTIMUM and GROWER agree that judgment may be entered upon any arbitration award in any court of competent jurisdiction.

c. Neither OPTIMUM nor the GROWER may assign this agreement without prior written consent of the other party. Written notice to OPTIMUM shall be by personal delivery or by postage paid letter addressed to Optimum Quality Grains, L.L.C., PO Box 2, Johnston, IA 50131-0002

8. LAND OWNER

If GROWER does not own a field used for the production of the OPTIMUM GRAIN under the terms of this Agreement, he/she shall indicate the name(s) of the owner(s) below. Any method of payment other than directly to GROWER shall be indicated below.

9. ACCEPTANCE BY OPTIMUM and ELEVATOR'S RIGHT OF REFUSAL

This Agreement is not binding until signed by both GROWER and OPTIMUM. GROWER must present this Agreement to ELEVATOR for OTPIMUM to sign.

ELEVATOR reserves the right, at its sole discretion, to refuse to accept this Agreement from GROWER prior to its being signed by OPTIMUM. If ELEVATOR chooses to exercise this option, ELEVATOR will notify GROWER that GROWER'S offer to produce OPTIMUM GRAIN has been rejected.

OPTIMUM QUALITY GRAINS, L.L.C.:
By:

_____Date:_____

GROWER:
By:

_____Date:_____
GROWER (signature)

When filling out the information below please PRINT CLEARLY with a ball point pen:
Grower Name: **GrowerDisplayName**
Company Name (if any): **CompanyDisplayName**
Street or box number: **ADDRESS1, ADDRESS2**

City, State, Zip Code, Phone: **CITY, STATE PostalCD, PHONE**
**Complete, legible name and address required for Agreement to be valid.
NON-OBJECTION BY LANDOWNER(S):

By:

_____
LANDOWNER

_____
ADDRESS/TOWN

* Optimum® is a registered trademark of Optimum Quality Grains, L.L.C.
* TC BLEND® is a registered trademark of Optimum Quality Grains, L.L.C.
Version: Version

Attachment A

OPTIMUM® HIGH OIL CORN
SEED COMPANY LIST FOR 2000

Ag Source	Horizon Seed Genetics
Ag Venture, Inc.	Hughes Hybrids
AgriGold	L. G. Seeds, Inc.
Agripro Seeds, Inc.	Legend Seeds, Inc.
Asgrow	Lewis Hybrids, Inc.
Beck's Superior Hybrids, Inc.	Mark Seed Company
Bo-Jac Hybrid Corn Co.	NC+ Hybrids
Brown Seed Farms, Inc.	Novartis Seeds, Inc.
Burrus Bros. & Assoc. Growers	Patriot Seeds, Inc.

Cargill
Callahan Seeds
Croplan Genetics
Crows Hybrid Corn Company
DeKalb Genetics Corporation
Diener Seeds, Inc.
Garst Seed Company
Golden Harvest/Garwood
Golden Harvest/Golden Seed Co.
Golden Harvest/JC Robinson Seed Co.
Golden Harvest/Sommer Brothers
Golden Harvest/Thorp
Great Lakes Hybrids
Growmark, Inc.
Gutwein, Fred & Sons, Inc.
Hawkeye Hybrids, Inc.
Hoblit Seed Co.
Hoegemeyer Enterprises, Inc.

Pfister Hybrid Corn Company
Pioneer Hi-Bred International, Inc.
Prime Farm Seeds, Inc.
Producers Hybrids, Inc.
Sand Seed Service
Schlessman Seed Co.
Seed Consultants
Select Seed Hybrids, Inc.
Sieben Hybrids, Inc.
Stewart Seeds, Inc.
Stone Seed Farms, Inc.
Top Farm Hybrids
Trelay Farms, Inc.
Trisler Seed Farms, Inc.
UAP Seeds Co.
Wilson Seeds, Inc.
Wyffels Hybrids, Inc.

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