Investment in a Thin and Uncertain Market: A Dynamic Study of the Formation and Stability of New Generation Cooperatives

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Steven Jerry Holland

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Robert King, Advisor

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This is to certify that I have examined this copy of a doctoral dissertation by

Steven Jerry Holland

and have found that it is complete and satisfactory in all respects,
and that any and all revisions required by the final
examining committee have been made.

Robert King
Faculty Adviser

Robert P. King

Robert King

May 6, 2004

Date

GRADUATE SCHOOL

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This dissertation is dedicated to Krista and our daughter Ava, who reminds us daily of the joy that comes from doing what you want. I love you both very much.

Abstract

Member-owned firms have become increasingly prominent in many industries, including the ethanol industry. Despite an upsurge in the popularity of member-owned firms, especially the new generation cooperatives (NGC's) that now dominate Minnesota's ethanol industry, there has been little research directed toward understanding why NGC's might proliferate in one industry while investor-owned firms are more prevalent in others. There are three main objectives in this study.

The first objective is to analyze producer investment in a new generation ethanol cooperative. This study shows that the traditional net present value rule of investing does not provide an adequate model of investment when volatile prices make returns uncertain and when an investment provides significant diversification benefits. An agent's true demand for NGC shares is often well below the investment threshold predicted by the traditional net present value rule.

The second is to model the market for stock in NGC's under various assumptions about the stock trading mechanism and to explore the investment and disinvestments decisions of members and the cooperative under each assumption. It is shown that the method by which the stock is traded has an effect on the value of the stock, the liquidity of the stock, and ultimately the ability of the cooperative to form and survive.

The third objective is to apply the model to two policy issues that are currently important to the ethanol industry: the threat of takeover of NGC's by investor-owned firms (IOF) and the impact of the ethanol subsidy on the formation and stability of ethanol plants. First, takeovers of NGC's are most likely to occur when the ethanol price and the corn price are both low because IOF's and NGC members respond differently to price risk. With respect to ethanol subsidies, it is shown that removing the ethanol subsidy would result in fewer ethanol plants, but those that do form would most likely be NGC's. Existing NGC's would also be less likely to be taken over by IOF's if the ethanol subsidy were eliminated, although more NGC's would be abandoned by their members.

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CHAPTER 1

INTRODUCTION

1.1 OVERVIEW

Economic theory regarding the organization of member-owned firms (cooperatives) has evolved over the last forty years from one primarily concerned with the objective of the cooperative (Helmberger and Hoos, 1962) to one that focuses on the goals and incentives of the firm's individual members (Staatz, 1983; Sexton, 1986). However, the last two decades have seen changes in the organization of cooperatives that have outpaced the economic theory. Perhaps the most important development in the cooperative movement over that time has been the introduction of so-called, "New Generation Cooperatives" (NGC's). These are member-owned firms in which the property rights associated with ownership are expanded beyond those found in traditional cooperatives. Most importantly, shares in a NGC are tradable and endowed with the right and obligation to deliver raw materials to the cooperative.

There has been an increasing amount of literature on new generation cooperatives in recent years, but as yet there has been little research to explain the incentives that motivate NGC formation. This is an important question because traditional cooperatives are seemingly in decline while NGC's have ignited what some cooperative enthusiasts have called "co-op fever" (Harris, *et. al.*, 1996, p.15). NGC's have already become the dominant type of member-owned firm in sectors such as the ethanol industry, and some states have even adopted legislation to specifically accommodate the innovative property rights structure of the new generation cooperatives (e.g. Wyoming and Minnesota).

Despite the relative importance achieved by NGC's in their short history, there are signs that they are not a panacea (see Torgerson, 2001). A number of prominent NGC's have struggled and been forced to abandon their cooperative status by reorganizing or selling their assets to an investor-owned firm.[1] Economic theory has thus far offered few explanations for these incidents.

These observations raise three issues that are important to NGC's. The first is the effect on the NGC from having tradable shares. Tradable shares were introduced to give NGC members the potential for a more immediate return on their investments and to boost the cooperative's ability to raise capital. However, the relative homogeneity of a NGC's membership often results in a very thin market for the NGC's stock and raises questions about how much tradable shares actually improve the liquidity of the investment.

The second issue is the ability of NGC's to form. The main purpose of the new generation cooperative organizational form is to make it easier for cooperatives to raise capital. At times there are bursts of NGC formations which suggests the new form of cooperative serves its purpose. But these bursts are not usually sustained and it is unclear whether economic conditions or governmental support are driving these trends.

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[1] Minnesota Corn Processors in Marshall, Minnesota and ProGold in Wahpeton, North Dakota are two corn processors that were forced to "demutualize." Even some apparently successful NGC's, such as Dakota Growers, have converted to limited liability companies. "New-generation co-ops adapt in tough times," *Feedstuffs*, Vol.74, No.41 (Oct. 7, 2002).

Finally, NGC supporters have become concerned about NGC's being taken over by investor-owned firms (IOF's). Archer Daniels Midlands' purchase of Minnesota Corn Processors has highlighted the issue. The threat of a takeover is a concern to members, who often form cooperatives specifically to counteract market power by IOF's, and regulators, who may question the wisdom of subsidizing cooperatives if many of them ultimately convert to IOF's.

This study is intended to be an initial step toward a more complete theory of the formation and stability of new generation cooperatives and will attempt to address these three issues. To that end, there are three main objectives of this study. The first is to analyze producer investment in a new generation ethanol cooperative. The second is to model the market for stock in NGC's under various assumptions about the stock trading mechanism and to explore the investment and disinvestments decisions of members and the cooperative under each assumption. The third is to apply the model to two policy issues that are currently important to the ethanol industry: the threat of takeover of NGC's by investor-owned firms and the impact of the ethanol subsidy on the formation and stability of ethanol plants.

Individual agents will enter or exit a NGC when it is advantageous for them to do so (Sexton, p.214). However, this study expands prior "theory of the firm" models of traditional cooperatives in two important ways. First, the unique property rights that come with owning shares in a NGC are considered. Since shares in a NGC are tradable, the nature of the market for these shares becomes important to understanding NGC behavior. This study looks at three possible market types: perfect competition, discriminatory auction, and competitive auction markets.

Second, agents are placed in a dynamic setting and are forced to optimize in the face of considerable uncertainty. This is important because members typically invest in NGC's to improve overall returns and to diversify their asset portfolios. The use of stochastic dynamic programming techniques allows for an analysis of the additional risk created by the tradable shares and the tight link between ownership and patronage associated with NGC membership.

1.2 BACKGROUND

1.2.1 The Role of New Generation Cooperatives in the Cooperative Movement

There are many definitions of a "cooperative" and many statements of the principles that guide cooperative decision making. The characteristics which seem to be common to all cooperatives are: (1) members control the cooperative through a democratic voting process, (2) members own the cooperative by providing all of its equity, and (3) members benefit from the cooperative by receiving favorable prices or distributions based upon patronage (Barton 1989, p.27). Traditionally, agricultural cooperatives have also followed the principle of open membership, which allows any agricultural producer to join and use the cooperative.

The traditional cooperative structure has been challenged. Over the last fifty years the number of agricultural cooperatives and the number of producers who are members of cooperatives have been in steady decline (see Figure 1.1, USDA, 1996). During this same time period, however, cooperatives' share of the market has increased slightly (see Figure 1.2, USDA, 1996). These statistics reveal a trend of small cooperatives either failing or merging into larger cooperatives. These larger cooperatives, in turn, are being owned by fewer, but bigger, producers. Small, local cooperatives with grass-roots origins still play a role but are increasingly scarce.

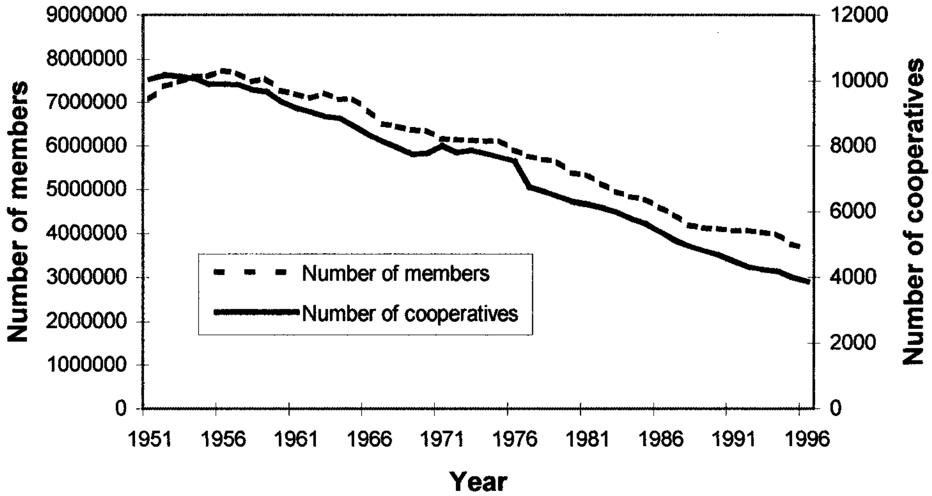

Figure 1.1
Number of Marketing and Supply Cooperatives and Number of Members

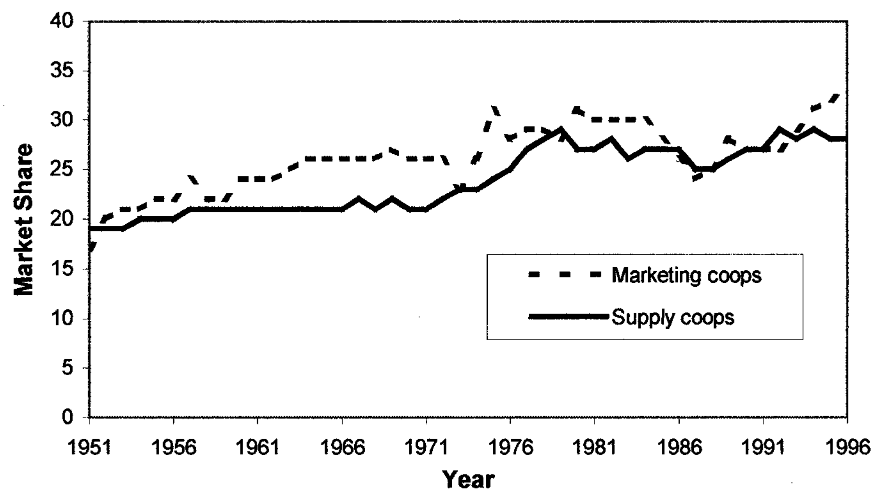

Figure 1.2
Market Share of Marketing and Supply Cooperatives

A major reason open-membership cooperatives have recently had a difficult time forming is that they have had trouble raising capital. Creating a value-added processing facility, such as an ethanol plant, requires a huge amount of capital, but members of a traditional cooperative may not have incentives to invest sufficiently. Two reasons are usually cited for this problem.[2] First is the free-rider problem. This arises because the benefits from membership in a traditional cooperative are tied to a member's level of patronage but not directly to the percent of ownership. Therefore, members have no incentive to increase their investment in the cooperative, and it becomes nearly impossible for the cooperative to raise sufficient funds to build a processing plant. Second, the cooperative's benefit structure gives members incentive to invest in projects that promise positive patronage returns in the short run. However, large processing facilities typically pay off only in the long run.

The difficulties faced by traditional cooperatives often do not go away after they overcome the equity hurdle. Cook describes the main reasons traditional cooperatives tend to be unstable (1995, p.1156-57). Most of these are related to the absence of a market for members to trade their interests in the cooperative. The lack of tradable rights implies that all members hold the same equity redemption rights regardless of how long they have been members of the cooperative. The lack of capital appreciation means members are not compensated for the time value of their investment and this creates a disincentive for agents to invest in the first place (Cook, 1995, p.1156). This disincentive is reinforced by the fact that redemption of equity

[2] Harris, *et. al.* (1996, p.18-20) contains a good description of the capital acquisition problem and the reasons why a new generation cooperative may be able to overcome these problems. This section follows their discussion

contributions is often delayed for years after the agent ceases to be an active member. The inability of a member to trade his interest in the cooperative also makes it more difficult for him to adjust his individual investment portfolio. All of these facts put pressure on the cooperative's board to follow policies that appease members' short-term interests even when doing so may not be in the best interest of the cooperative.

New generation cooperatives were designed to overcome some of these problems by strengthening the tie between ownership and patronage and allowing the transfer of NGC shares. The recent popularity of NGC's makes it appear they are succeeding. The first NGC was formed in 1973 by sugar beet growers in North Dakota and Minnesota, but there was very little development of new generation cooperatives until the mid-1980's. From that time to 1999, however, an estimated 125 NGC's have formed, primarily in Upper Midwestern states (Cook and Illiopoulis, 1999). Many more are purported to be in the works. Nearly all of these NGC's have been formed to build value-added processing facilities that most traditional cooperatives could not possibly finance.

The strong link between ownership and patronage is created because each share of NGC stock carries the right and obligation to deliver a predetermined quantity of product to the cooperative (Harris, *et. al.*, p.17). For example, one share in an ethanol cooperative gives the shareholder the right and obligation to deliver one bushel of corn to the NGC. The shareholder benefits from the guaranteed market for his goods but also accepts the duty to deliver the amount promised. In a traditional cooperative, the member could vary his patronage of the cooperative without altering his ownership interest. In a new generation cooperative, a member's level of patronage can be changed only by buying or selling shares in the NGC.

As a practical matter, the tight link between ownership and patronage demands that the NGC carefully consider both production capacity and equity requirements early in the formation process. When deciding how many shares to initially offer for sale the NGC first determines how much raw material it wishes to process. Ideally, a cooperative will process the amount that results in the most efficient operation (Harris, *et. al.* p.16). For instance, if an ethanol plant wanted to process one million bushels of corn it would offer to sell one million shares, each of which carries the duty to deliver one bushel of corn.

The cooperative then prices each share to raise the necessary amount of capital. For example, if the NGC described here needs to raise $4 million, it would offer to sell its one million shares at $4.00 per share. Typically, a NGC will attempt to raise 30-50 percent of the cost of the processing plant and finance the balance (Harris, *et. al.*, p.18).

It is widely believed that forcing members to purchase a quantity of shares that is commensurate with their use helps NGC's overcome the equity problem faced by traditional cooperatives. The free-riding problem is reduced since members are foreclosed from the benefits of patronage without a proportionate ownership interest, spurring investment and making it easier for the NGC to raise the required capital. The NGC also gets a reliable source of supply and members get a guaranteed outlet for their goods.

Tradable shares alleviate member concerns about having money sunk into the cooperative with no prospect for a reasonable return or timely redemption. Tradable shares allow members to adjust their portfolios on an ongoing basis rather than waiting years for an equity redemption. Members are also able to realize a return on their investment by trading individual shares rather than forcing the liquidation of the NGC. Both of these features make the NGC look more appealing to investors than a traditional cooperative.

While NGC's have created much excitement in the cooperative community, they are not without problems. Patronage refunds are susceptible to fluctuations in the cooperative's profit, which is at the mercy of volatile input and output prices. The "obligation" portion of the NGC ownership package adds additional risk to the investment because satisfying it could be costly if the member's corn yield is unexpectedly small or if a much better corn price is being offered elsewhere.

New generation cooperative members could be subjected to additional risk if the market for NGC stock is "thin." There are many definitions of a "thin market," but the common thread among those definitions is that a thin market has a relatively small volume of trades. (Nelson and Turner, p.150). NGC's can suffer from a low trading volume because the pool of potential investors is limited by geographic constraints and legal restrictions.[3] Relative homogeneity among possible investors also contributes to market thinness because a member's demand for NGC stock tends to be very similar to the demand of others, causing the market to be loaded with either buyers or sellers rather than maintaining a healthy balance of both.

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[3] State and federal laws restrict membership in agricultural cooperatives to agricultural producers.

There are two main effects of market thinness. The first is that farmers wishing to buy or sell shares may not be able to find a trading partner. The inability to trade shares may prevent a member from locking in a capital gain or adjusting his portfolio and may block entry for potential members. The result is almost assuredly a sub-optimal level of ownership and a reduction in the member's welfare. The second effect of a thin market is greater share price volatility. (Pagano, p. 269). When a market has fewer traders, market prices are more sensitive to shocks and aberrational behavior by traders than they would be in a more liquid market. Pagano argues persuasively that price volatility in a thin market is self-perpetuating because greater price variance drives out investors, making the market thinner and further increasing the risk to those who remain.

Some NGC's have suffered from these problems and been forced to abandon their cooperative status. For example, in September 2002 members of Minnesota Corn Processors (MCP), at one time the largest new generation ethanol cooperative in the country, voted to sell all of their shares to Archer-Daniels-Midland (ADM). Financial problems had already forced MCP to convert to a limited liability company, eliminate member delivery obligations, and sell 30 percent of its stock to ADM. At the time of the sale MCP stock was trading at $1.00 per share, which was substantially less than most members had paid for it. ADM offered $2.90 per share and 81% of MCP members voted in favor of the sale.[4] The MCP story, as well as other factors, make the ethanol industry a good context to explore the questions of why NGC's form and fail.

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[4] "Poor business choices prompted MCP sale to ADM," *Feedstuffs*, Vol. 74, No. 41, p.1 (Oct. 7, 2002).

1.2.2 The Ethanol Industry

Ethanol is derived from corn and can be blended with gasoline to promote a more complete, and consequently cleaner, burning fuel (Tiffany, 2002). Since ethanol is generally more expensive than gasoline, the petroleum industry has no natural incentives to blend ethanol into gasoline. Instead, the demand for ethanol is created through a system of government subsidies and blending mandates, which proponents argue are necessary to prop up depressed corn prices, spur rural economic development, reduce CO_2 emissions, and decrease dependence on oil imports (Ye, 2002, p. 1).

Minnesota state law now requires that gasoline be at least a 10% blend of ethanol. This requirement creates a demand for approximately 250 million gallons of ethanol per year. Recent bans on MTBE's, another gasoline blending agent that is believed to be a carcinogen, will likely result in an even larger market for ethanol. The Federal government exempts ethanol producers from $0.054 per gallon of the gasoline excise tax. Given the ten percent blending requirement, this equates to a subsidy of $0.54 per gallon of ethanol produced. Other federal tax credits are also available for some small ethanol producers (Crooks, 1997, p.1). In 1986, Minnesota also enacted a $0.20 per gallon subsidy for producers of ethanol for the first 15 million gallons of ethanol produced (Minn. Stat. §41A.09). Recent amendments to the statute reduce total payments to about one-third of their former amount and stop the subsidies after ten years of operation (Minn. Stat. §41A.09, subd.3a), and there are signs that support for this program will continue to dwindle. It is estimated that state and federal subsidies comprise, on average, twelve percent of an ethanol plant's total revenue (Tiffany, 2002).

Ethanol is produced through either wet-mill processing or a dry-mill processing of corn. The more commonly used wet mill process is very similar to that used to produce alcoholic beverages. The corn is ground, mixed with water, and cooked. Starch is then converted into sugar and yeast is added to allow for fermentation. The resulting alcohol is distilled and turned into ethanol fuel and then denatured with a 5 percent blend of gasoline. Some dry by-products are also created which may be resold as livestock feed. (Crooks, p.3-4). One bushel of corn produces approximately 2.5 gallons of ethanol.

Cooperatives have played an important role in the ethanol industry. Cooperatives produce about 35% of the nation's ethanol, although estimates vary. In Minnesota, eleven of fourteen ethanol plants are currently owned in whole or in part by new generation cooperatives. These account for almost 85% of the ethanol produced in the state. [5] Most of the Minnesota NGC's have formed since the enactment of Minnesota's ethanol program.

1.3 COOPERATIVE THEORY

1.3.1 Traditional Approaches to Cooperative Purpose and Evolution

Historically, cooperatives have been viewed as necessary responses to adverse market conditions. Cook (1993, p.159) summarizes the primary motives behind cooperative formation. They are:

[5] Minnesota Department of Agriculture (www.mda.state.mn.us/Ethanol/about.htm).

1. To confront or avoid the monopolistic / monopsonistic behavior of firms with market power.

2. To take advantage of scale economies.

3. To reduce risk.

4. To provide services or goods that the market would not otherwise provide.

5. To improve margins through the exercise of market power.

The question of how cooperatives go about accomplishing these goals has been the subject of a broad range of "theory of the firm" type studies. A concise summary of the history of cooperative theory is contained in Torgerson, Reynolds and Gray (1998).

Theory suggests that cooperatives should be able to accomplish many, or all, of the goals identified by Cook. Nonetheless, the cooperative movement has endured only sporadic success and cooperatives have rarely gained the market share one might expect. (Cook, p.1154). Periods of interest in cooperatives have often been followed by widespread cooperative failure and the proliferation of investor-owned firms (IOF's). Figure 1.3, for example, shows the cyclical pattern of marketing cooperative formations and dissolutions of over a recent ten year period (USDA).

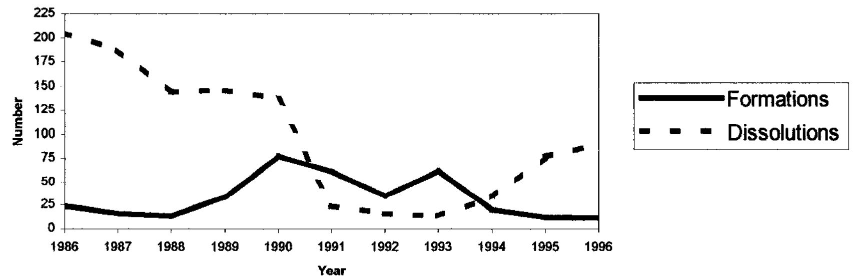

Figure 1.3
Marketing Cooperative Formations and Dissolutions (1986-96)

This pattern has inspired efforts to describe a "life-cycle" theory of cooperatives that explains why investors form, operate and abandon a cooperative. (*e.g.* Hind). Cook (1995, p.1155) summarizes the four most common theories of cooperative evolution:

(1) *The "Wave" Theory* – In depressed times there is a wave of cooperative formations, only to be followed by a subsequent wave of cooperative failures.

(2) *The "Wind-It-Up" Theory* – Cooperatives form in order to force the competition to give farmers more favorable terms. Once they have succeeded, however, cooperatives become obsolete.

(3) *The "Pacemaker" Theory* – Cooperatives must exist in order to promote greater efficiency among competing firms.

(4) *The "Mop-Up" Theory* – In declining markets, cooperatives form in response to opportunistic behavior by investor-owned firms.

As Cook points out, none of these theories provides a coherent explanation of how cooperatives form, grow, and then dissolve. Furthermore, all of these concepts are static. None considers the special property rights structure of NGC's, and none adequately considers the role of uncertainty.

1.3.2 Agent-Based Cooperative Models

The idea of a cooperative as an aggregate of its individual members rather than a distinct, optimizing entity began with Emelianoff (1942). In that work, cooperatives were first conceptualized as a means for members to achieve vertical market integration. Following Emelianoff, different forms of agent-based cooperative models appeared with various degrees of success (Torgerson, *et. al.* p.5).

In the 1980's agent-based cooperative theory began to view cooperatives as a coalition of members that could be modeled as an *n*-person cooperative game.

(Staatz, 1983; Sexton, 1986). Staatz dealt primarily with the question of how decisions were made within an open membership cooperative. His work was unique at the time because it used *n*-person cooperative game theory to address the problems raised by a heterogeneous membership. Staatz observed that the gains created by a cooperative depend on the size and characteristics of the cooperative's membership and that the cooperative's members are likely to have differing views on how those gains should be allocated. If a member is unhappy with his share of the cooperative's gains he could either leave the cooperative or use the threat of leaving to force the cooperative to change the manner in which gains are allocated. Staatz used the concept of the "core" to describe how a cooperative's policies could be tailored to obtain the set of feasible allocations that give the most members an incentive to stay in the cooperative.

The main conclusion of Staatz's analysis was that differential pricing of the cooperative's services is an optimal policy. The manner in which a cooperative prices its services (*i.e.* allocates its gains) should reflect a member's impact on the cooperative's costs and be responsive to the alternative opportunities available to members. He concluded that large members would be most likely to extract favorable concessions from the cooperative and small members would be least likely to do so. While Staatz' analysis focused on the decision-making of an existing cooperative, he also noted that the optimal size of a cooperative may depend on the cooperative's cost structure. This observation may have been a precursor to further studies that looked explicitly at cooperative formations.

The most prominent of these is by Sexton (1986). He extended the *n*-person cooperative game to the questions of the formation and stability of open membership cooperatives. Along the lines of Staatz, Sexton noted that agents will join a cooperative if doing so is beneficial. Consequently, a stable cooperative must provide benefits at least as great as those its members could obtain elsewhere. Again using the concept of the core, Sexton analyzed both cooperative structure and the allocation of payoffs.

Sexton concluded that when the set of payoffs is superadditive (*i.e.* there are gains from coalition building) a single cooperative, as opposed to multiple cooperatives, is the optimal coalition structure. This is always true when the cooperative's average cost is non-increasing and is usually true when it is increasing. However, if the set of payoffs is not superadditive then a multi-cooperative structure is optimal. Consistent with Staatz, Sexton concluded that marginal cost pricing is optimal for the stability of the cooperative because it appeals most to agents with elastic demand for the cooperative's services.

The general approach taken by Staatz and Sexton is useful, but there are a number of reasons why cooperative game theory is not the most appropriate framework for NGC's. In the open membership cooperatives addressed by Staatz and Sexton, all benefits from membership come from a member's patronage of the cooperative. The allocation of these benefits is determined by the cooperative's management. Therefore, members have incentives to influence management through the use of threats and negotiation. Cooperative game theory is appropriate in that circumstance.

In new generation cooperatives the benefits of membership come both from patronage and from ownership of the NGC's stock. Patronage benefits are the same for each unit of stock issued by the NGC (*i.e.* there is no differential pricing), so there is less incentive for members to pressure management for preferential treatment. Instead, members can directly alter their allocation of the NGC's benefits by buying or selling stock. In other words, a NGC's gains are allocated through a system of autonomous member decisions and market mechanisms rather than through the process of coalition building. Therefore, a non-cooperative framework must be used to analyze NGC's.

The Staatz and Sexton models are also inadequate for a "life-cycle" theory of NGC's because they are static and the agent's payoffs from cooperative membership are deterministic. Cook noted that a dynamic theory is required in order to reach an understanding of the reasons for cooperative formation and decline (Cook, 1995, p.1155). This is particularly true in the case of NGC's because the risk associated with owning a share is a critical factor in a member's decision to invest or disinvest, and this changes over time as prices evolve and the composition of the NGC membership shifts. Drawing upon the theory of investment under uncertainty can help add the dynamic element missing from traditional cooperative theory.

1.3.3 Investment Under Uncertainty

An agent considering an initial investment in a new generation cooperative has two choices – invest now or wait. Increasing the level of investment in the NGC increases a risk-neutral agent's utility so long as the expected return is large enough, over a sufficient length of time, to cover the cost of investing. Waiting, however, allows the agent to see what prices and yields will be in the next time period. If current market conditions are such that investment is expected to be only marginally profitable, then the benefit of waiting for some uncertainty to be resolved may be substantial. If conditions are such that the investment is likely to increase utility regardless of what happens in the future, then waiting may have little value. A rational agent will assess both the value of investing and the value of waiting before making a decision.

This is the general approach taken by Dixit and Pindyck (1994), and is often called the "real options" approach to analyzing investment decisions. In the book, *Investment Under Uncertainty*, Dixit and Pindyck have set forth a number of methods to analyze investment decisions in the presence of uncertainty which are particularly apt for addressing the question of investment in new generation cooperatives.

The traditional method for analyzing investment decisions is to use the net present value (NPV) rule. The NPV rule says that the optimal investment decision is to invest when the discounted expect return from the investment is sufficient to cover its cost. The real options approach differs from the NPV approach because the "true cost" of investing includes not only the monetary expense of investment but also the opportunity cost of giving up the option to wait.

An investment opportunity (*i.e.* the option to invest) gives an agent the right to invest in some project at any time he sees fit. Holding an option to invest provides value to the option holder in two ways. First, assuming the cost of the investment is constant over time, waiting to invest (which can be thought of as holding, rather than exercising, the option) will allow an agent to enjoy any capital appreciation that occurs during the wait. Second, waiting is also valuable if the return on the investment is difficult to determine because of uncertain market conditions. In that case, the value comes from being able to wait for uncertainty to be resolved. Using dynamic programming methods, Dixit and Pindyck show how to determine the value of the option to invest as a function of the random state variables.

Of course, an active project also has value. Owning an asset entitles the owner to a certain cash flow as well as a capital gain. By investing in the project, an agent will be entitled to these benefits and will also gain the right to disinvest in the future. Therefore, the value of the active project, which is also a function of the state variables, can be viewed as the sum of expected cash flow, expected capital gains and the value of the right to abandon the project.

When an agent invests, he gets the value of the active project but gives up the value of the option to wait. Comparing these values provides insights into the agent's optimal investment decisions. For example, if an agent has not yet invested in a cooperative and the value of the active investment minus the cost of investment is greater than the value of waiting, then the agent should invest immediately. If the value of waiting is greater, he should not. If, on the other hand, an agent has already invested in a cooperative he must make the decision whether to maintain his investment or to sell it. In that case, if the value of staying in the cooperative is greater than the value of not being in the cooperative (*i.e.* regaining the value of waiting) less the cost of abandonment, the agent will not sell his stake.

The most realistic model allows the producer to choose a level of investment and then adjust the size of his investment (by buying or selling) in each time period. Dixit and Pindyck (Ch. 11) show that analysis of incremental investment decisions of this type is analogous to the problem of binary investment decisions. For example, a risk averse agent will realize diminishing marginal utility as the size of his investment grows, so each successive block of stock can be thought of as a separate investment with its own marginal value that is less than the marginal value of the previous block. For each discrete block of investment, then, there is some threshold level of expected cooperative profitability that will make it worthwhile for the producer to purchase the stock. The producer will continue to purchase blocks of stock until the marginal value of buying the next block is less than the cost of buying that block.

There are two important implications of using the real options approach rather than the net present value approach. The first is that uncertainty increases the value of waiting and, thus, more favorable market conditions will be required before it is rational to make an investment. When, for example, the profitability of a NGC is uncertain due to randomness in the price of corn and the price of ethanol, a producer has some incentive to wait in order to observe the direction of prices in the next time period. If the variance of the corn price and ethanol price were to increase, the producer would find it even more difficult to predict the future value of his investment and more favorable conditions would be required to entice him to invest. The second implication is that when an investment is not completely reversible an agent will favor the *status quo*. For example, if there are significant transaction costs associated with trading NGC shares, if the stock were to depreciate, or if there were some possibility of not being able to sell at all, then an agent may delay changing his stock holdings. In other words, when it is costly to change one's mind it is rational to wait even longer before making an irreversible or partially irreversible decision.

1.3.4 Dynamic Models of New Generation Cooperatives

Any model of new generation cooperatives must recognize the unique property rights structure of NGC's and be dynamic in nature. A few recent studies have used that approach.

Sporleder and Bailey (2001) applied real options methods to new generation cooperatives and found, consistent with Dixit and Pindyck's analysis, that "decision-making flexibility" adds value to the NGC investment. Sporleder and Bailey were able to simulate investment in a new generation cooperative and project the value of a share in a proposed tortilla-processing cooperative. However, that paper does not consider alternative trading mechanisms and the NGC's formation or failure is exogenous to their model.

Zeuli (1998) compared NGC's with investor owned firms and traditional cooperatives by modeling investment in these organizations as a portfolio problem. She found, among other things, that organizing a processing facility as a new generation cooperative offers members a greater expected utility than if the facility was organized as either an IOF or a traditional cooperative. Agents in Zeuli's model are heterogeneous and risk averse, but she also presupposes the existence of the various organizations and does not consider the impact of various stock trading mechanisms on the risk of owning NGC's.

1.4 THESIS OUTLINE

The structure of this study follows its three main objectives. The first objective is to analyze producer investment in a NGC. This study does this by employing a series of discrete-time, stochastic dynamic programming models to analyze individual agent decisions about investment in a new generation cooperative. The second objective is achieved by linking the agent models and identifying the conditions where NGC's will attempt to form or, conversely, where they will exit the market. Examining the results of individual agent models also provides insights into the incentives that drive cooperative formation. Simulations of the NGC stock markets reveal information about share price dynamics, trading volume, and the distribution of agent types in the cooperative's membership. Piecing together these bits of information and comparing results across different market types begins to form a more complete picture of why NGC's exist. The third objective, analyzing the threat of takeovers and the impact of ethanol subsidies, is a straightforward application of these models.

Chapter 2 sets forth the model in its most general terms. The primary focus of Chapter 2 is to specify the agents' objective function and dynamic programming problem. In addition, the stochastic variables and the model's significant parameters will be discussed. The dynamic programming problem set out in Chapter 2 is complex enough that numerical solution methods must be used, but in Chapter 3 the problem is simplified and solved analytically. The goal of Chapter 3 is to contrast two possible responses an agent may have to uncertainty. These conflicting responses are delaying investment until the uncertainty is resolved and diversifying through increased investment.

Chapters 4 and 5 explore NGC formations, share trading and exit decisions under different market settings. Chapter 4 deals with the situation where a NGC's shares are traded through a competitive market and Chapter 5 looks at discriminatory auction and competitive auction markets. Both chapters begin with the numerical solution to the individual agents' problems. In these sections agents' demand for NGC shares and their threshold for initial investment are examined. The second half of each chapter focuses on the results of the market simulations of trading behavior and share prices. The NGC's formation thresholds, share price dynamics, trading volume, membership characteristics and exit thresholds are discussed. Chapter 5 also includes a comparison of the two auction market types.

A model of an investor-owned firm is introduced in Chapter 6. In that chapter, the investment thresholds for the different organizational types are compared and the question of whether an IOF or a NGC is likely to form is answered. Then, the NGC's exit thresholds are compared to the IOF's investment threshold and a range of states where takeovers of the NGC are likely to occur is identified. The second part of Chapter 6 extends the analysis by looking at the impact on NGC entry and exit conditions from altering the level of government subsidies.

CHAPTER 2

THE GENERAL MODEL

2.1 OVERVIEW

This study analyzes the investment behavior of agents in four different settings. In the first three settings agents are corn producers who must choose a level of investment in a new generation cooperative (NGC) that owns and operates an ethanol plant. These settings differ by the method in which shares of the NGC are traded. The three methods are a competitive market, a discriminatory auction market and a competitive auction market. In the fourth setting, the agent is an investor-owned firm (IOF) which does not produce corn but still must choose whether to invest in an ethanol plant. This chapter focuses on the problem faced by the producer agents, although most of the discussion will also be relevant to the IOF's problem described in Chapter 6.

The first type of NGC is one that has achieved a competitive market for its shares. A "competitive market" in this context is one where there are enough potential buyers and sellers of NGC shares in each time period to make the market for NGC stock perfectly liquid. In essence, each agent submits a demand schedule for NGC shares and the market clears at the price at which aggregate demand is equal to zero. Each agent can trade as many shares as he wishes at the current market-clearing price.

The second type of NGC is one where cooperative shares are traded through a multi-unit, discriminatory auction. In a multi-unit, discriminatory auction, every agent submits an optimal quantity / price pair at the beginning of each time period. The quantity may be positive (a buyer), negative (a seller), or zero. A buyer's price is a bid and a seller's price is a reserve price. After all of the quantity / price pairs are submitted, an "auctioneer" prepares a schedule of aggregate supply and demand and identifies and matches successful buyers and sellers. Successful buyers always pay their bid price while the price received by a successful seller depends upon which buyer purchases her shares.

The third type of NGC is one that uses a multi-unit, competitive auction trading mechanism. The bidding mechanism of the competitive auction is identical to the discriminatory auction mechanism. The difference between the two types of auction is in the price at which shares are traded. In a discriminatory auction each trade occurs at the price bid by the buyer, but in a competitive auction every trade in a given time period occurs at the same market-clearing price.

The nature of the stock trading mechanism impacts an agent's optimization problem. Most significantly, in the competitive market optimization problem the NGC share price is a state variable and the quantity of shares to be traded is the choice variable. However, in the optimization problems for the auction markets, agents choose both a quantity to be traded *and* a share price. In the auction markets and agent is not guaranteed to be successful, so the optimization problem involves an expected probability of success. The NGC share price dynamics are also affected by the nature of the stock trading mechanism employed.

In spite of these specific differences, the general structure of the agent's problem across the three trading mechanisms is very similar. For instance, each agent's risk preference is represented by an additively time-separable utility function with positive, non-increasing marginal utility. The goal of each agent is to maximize the expected utility of net cash flows over an infinite planning horizon. An agent's net cash flow in a given year includes the net income from farming, the net income from any ownership share in a NGC, and the expense (revenue) from buying (selling) shares in the cooperative[1]. In each case, net cash flow is subject to uncertain ethanol prices, corn prices, share prices and corn yields. Ethanol and corn prices follow the same stochastic process in each market and corn yields have the same mean and variance. Each NGC type owns an identical ethanol plant, and the population of potential investors has the same characteristics.

These similarities make it desirable to begin with a generalized optimization problem that is applicable to agents in each type of market setting. The next section does that. The remaining sections of this chapter describe the specific components of the optimization problem that are common to all of the market types: (1) the net cash flow function, (2) the dynamics of the corn and ethanol prices, and (3) the characteristics of the agent population and the ethanol plant. Those portions of the optimization problem that are specific to a certain market type will be discussed in the subsequent chapter dealing with that market type.

2.2 THE AGENTS' GENERAL OPTIMIZATION PROBLEM

This is a dynamic model with discrete time and continuous states. In each setting the states include the ethanol price, corn price and agent's share balance. The share price is also a state variable if the agent is in the perfectly competitive market.

[1] The cost of borrowing money to purchase NGC shares is ignored.

Given the observed states, the agent forms expectations about the future and chooses an optimal policy to maximize the expected utility of net cash flow over an infinite planning horizon. In general, the subscript t is assigned to states the agent is able to observe at the time he chooses his optimal policy. The optimal policy in a competitive market is a quantity of shares to be traded, but it is both a quantity and share price if he is in either of the auction markets.

After determining the optimal course of action, the agent observes new states and the current period's corn yield and then realizes the current period net cash flow. Each agent's net cash flow (NCF) is a function of the new corn price (CP_{t+1}), the new ethanol price (EP_{t+1}), the number of shares owned in the previous period (SH_t), and the number of shares offered for purchase or sale (X_t). NCF is also a function of the share price (SP_t) which is known in the perfectly competitive market and unknown in the auction markets. Since the corn and ethanol prices that will determine the current period's cash flow are unknown at the time the agent chooses his optimal policy, the net cash flow function is a random variable. Its specific functional form will be described in Section 2.3.

Every agent exhibits some level of risk aversion. Risk aversion is modeled using a negative exponential utility function of the form, $U(\Pi) = -\exp^{-\lambda(\Pi)}$, where λ is the coefficient of risk aversion and Π is the net cash flow function.

The essential feature of a dynamic model is that investment decisions affect not only net cash flows in the current period but also opportunities for future net cash flows. The evolution of these opportunities is modeled with state equations for the corn price, the ethanol price, the share price, and the share balance.

In each of the models, the corn price and ethanol price follow non-stationary processes. The general form for the corn price state equation is denoted by $CP_{t+1} = h(CP_t, \varepsilon_t^C)$ and the general form for the ethanol price equation is $EP_{t+1} = j(EP_t, \varepsilon_t^E)$. In both cases, the error terms (ε) have a mean of zero and variances of σ_C^2 and σ_E^2, respectively. An analysis of historical corn and ethanol prices and a discussion of specific functional forms are contained in Section 2.4.

The evolution of share prices is different for each market setting. In general, the share price state equation is denoted by $SP_t = g(EP_t, CP_t, SP_{t-1}, P_t, \varepsilon_t^S)$, where ε_t^S is a random variable and P_t is the bid price in the auction markets. Not all arguments necessarily have an impact on the share price dynamics in a particular market setting

In the competitive market the share balance is deterministic, but under the auction market structure the share balance resulting from the agent's optimal policy is uncertain because the agent does not know whether the quantity / price pair he submits to the auctioneer will result in a trade. Therefore, a general specification for the dynamics of share balance is $SH_{t+1} = f(EP_t, CP_t, SH_t, SP_t, X_t, Q_t, \varepsilon_t^X)$, where ε_t^X is a random variable, Q_t is the bid quantity in the auction markets, and, again, not all arguments necessarily have an impact on SH_{t+1}. For agents in all of the trading scenarios, shares are traded in 1000 share increments and share balances must remain nonnegative and below a maximum share balance[2]. It is common in ethanol cooperatives for the NGC to require members to hold at least 5000 shares. This model also imposes that constraint.

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[2] The maximum share balance is determined by the expected corn yield times the number of acres of corn in production. This constraint was not binding for any agent in any simulation performed in this study.

The agent's utility function varies depending on the nature of the stock trading market. For the perfectly competitive market, the utility function takes the general form:

$$U[\Pi(CP_{t+1}, EP_{t+1} \mid SP_t, SH_t, X_t, \varepsilon_t)].$$

In the auction markets the utility function's general form is:

$$U[\Pi(CP_{t+1}, EP_{t+1}, SP_t, X_t \mid P_t, Q_t, SH_t, \varepsilon_t)].$$

The agents in this model face an infinite planning horizon. This assumption implies that agents are either far from retirement or that they plan to pass their business on to heirs. As a practical matter, an infinite planning horizon eliminates the need to keep track of an agent's wealth from one time period to the next and removes the need for an additional state variable. In an infinite horizon setting, the agent's general optimization problem is:

$$\max_{X_t} \sum_{t=0}^{\infty} \beta^t \mathrm{E}\left[U[\Pi(\cdot)]\right] \qquad (2.1)$$

subject to:

$$\begin{aligned} CP_{t+1} &= h(CP_t, \varepsilon_t^C) \\ EP_{t+1} &= j(EP_t, \varepsilon_t^E) \\ SP_t &= g(EP_t, CP_t, SP_{t-1}, P_t, \varepsilon_t^S) \\ SH_{t+1} &= f(EP_t, CP_t, SH_t, X_t, Q_t, \varepsilon_t^X) \\ 0 \le SH_t &\le SH_{\max} \end{aligned}$$

where β is a discount factor.

The optimization problem described in Equation 2.1 can be converted to a recursive problem if certain conditions are satisfied (Stokey and Lucas, 1989). The first condition is that $0 < \beta < 1$. This is satisfied by the assumptions of the model (see Appendix 2.1). The second condition requires that $U[\Pi(\cdot)]$ be bounded from above or below. The negative exponential utility function is bounded from above at zero, so the second condition is also met. Consequently, in the perfectly competitive market and at any time, *t*, the tradeoff between current returns and future opportunities can be represented by the Bellman equation:

$$W(EP,CP,SH,SP) = \max_{X}\left\{\begin{array}{r} \mathrm{E}\big[U[\Pi(EP',CP' \mid SP,SH,X,\varepsilon)]\big] \\ +\beta\mathrm{E}\big[W(EP',CP'SH',SP')\big] \end{array}\right\}$$

subject to:

$$\begin{aligned} &CP' = h(CP\ ,\varepsilon^{C}) \\ &EP' = j(EP,\varepsilon^{E}) \\ &SP = g(EP,CP,SP_{-1},\varepsilon^{S}) \qquad (2.2) \\ &SH' = f(EP,CP,SH,X,\varepsilon^{X}) \\ &0 \le SH' \le SH_{\max} \end{aligned}$$

In an infinite horizon problem the specific time period in which the agent finds himself is irrelevant, so subscripts can be dropped. For example, *SH'* is the share balance after the optimal policy is exercised (*i.e.,* $SH' = SH + X$).

Similarly, the tradeoff between current returns and future opportunities in the auction markets can be represented by the Bellman equation:

$$W(EP,CP,SH) = \max_{Q,P} \begin{Bmatrix} \mathrm{E}\left[U[\Pi(EP',CP',SP,X \mid P,Q,SH,\varepsilon)]\right] \\ +\beta\mathrm{E}\left[W(EP',CP'SH')\right] \end{Bmatrix}$$

subject to:

$$CP' = h(CP\ ,\varepsilon^{C})$$

$$EP' = j(EP,\varepsilon^{E})$$

$$SP = g(EP,CP,SP_{-1},P,\varepsilon^{S}) \qquad (2.3)$$

$$SH' = f(EP,CP,SH,X,Q,\varepsilon^{X})$$

$$0 \le SH' \le SH_{\max}$$

The left hand sides of Equations 2.2 and 2.3 represent the value function. The first term on the right hand side is the expected utility of net cash flow in the current time period, given the agent's optimal policy. The second term on the right side is the discounted value of the agent's decision going forward, assuming he continues to optimize in the future.

The solution to the Bellman equation is called the policy function. The advantage of converting the agent's optimization problem into a recursive problem is that the policy function is a unique, fixed-point solution under most conditions. Specifically, if the utility function is bounded and continuous and if the set of possible policies is non-empty, compact valued and continuous, then there will be a unique solution to Equations 2.2 and 2.3. (Stokey and Lucas, Ch.4). In this case, these conditions are satisfied except that the set of possible policies is discrete rather than continuous. As a result, multiple solutions could conceivably exist. To address this problem, if there is more than one policy that maximize an agent's value, it is assumed that the agent is indifferent between these policies and the computer has been programmed to choose the policy that is closest to zero.

The agent's problem in the competitive market contains four state variables and the agent's problems in the auction markets contain three. In all cases there are at least two stochastic state variables, so analytical solutions become prohibitively difficult if not impossible. However, numerical solutions to the various agent problems have been found using MATLAB and a revised version of a program initially developed by Heman Lohano (2002). Lohano's model implements methods described in Chapters 8 and 9 of Miranda and Fackler (2002).

2.3 NET CASH FLOW FUNCTION

Each agent's principle concern is his net cash flow, and the net cash flow function is identical for agents in each type of cooperative. The NCF function is comprised of (1) revenue resulting from ownership of cooperative shares, (2) revenue from outside of the cooperative, (3) the agent's cost of production, and (4) the expense (revenue) from buying (selling) cooperative shares. [3]

2.3.1 Cooperative Revenue

The first component of the NCF function is the revenue the agent receives from the cooperative. Payments from the cooperative could result from the agent's role as a supplier of corn to the cooperative or from his ownership interest in the cooperative. While both payments depend on the size of the agent's investment in the

[3] A producer's NCF function would also be affected by alternative investments such as stocks. In order to simplify the model, I ignore this possibility. This assumption is not entirely unreasonable since many producers have the majority of their wealth tied up in land.

cooperative, distinguishing between the farmer's dual role as vendor and owner helps to highlight the unique nature of the cooperative structure.

Suppose agent i owns SH_t^i shares in a cooperative in year t and then buys or sells X_t shares. In a new generation cooperative, the agent would consequently be required to deliver $SH_{t+1}^i = (S_t^i + X_t^i)$ bushels of corn to the cooperative in that year. The effective price the agent receives from the cooperative may vary depending on the agent's distance from the ethanol plant. This price difference is captured by the variable γ^i, which could be negative or zero and is constant over time. The agent's revenue from delivering corn to the cooperative is equal to the number of bushels delivered multiplied by the effective price:

$$\left(SH_t^i + X_t^i\right)\left(CP_t + \gamma^i\right) \tag{2.4}$$

In addition to being a supplier of corn, the agent is also an owner of the cooperative and is entitled to a proportional share of the cooperative's profit. A cooperative with N members earns profit in time t, Π_t^{coop}, equal to the amount of output, Z_t, multiplied by the price of the finished good, less the cost of raw materials and the cost of processing. Here:

$$\Pi_t^{coop} = Z_t\left[EP_{t+1} - CP_{t+1} - CAC\right],$$

where CAC is the cooperative's average cost of production (assumed to be constant over time).

The unit of measure for the cooperative's output, Z_t, is chosen so that $Z_t = \sum_{i \in N} SH_{t+1}^i$. In other words, all of the members' corn is processed, ethanol is made solely from member corn, and output is measured in bushels.[4] Since agent i's ownership percentage is $\left[\frac{SH_{t+1}^{i}}{\sum_{i\in N} SH_{t+1}^{i}}\right]$, the agent's share of cooperative profit can be simplified to:

$$\begin{aligned} &SH_{t+1}^{i}\left(EP_{t+1}-CP_{t+1}-CAC\right)= \\ &\left(SH_{t}^{i}+X_{t}^{i}\right)\left(EP_{t+1}-CP_{t+1}-CAC\right) \end{aligned}. \tag{2.5}$$

This assumes that the cooperative returns all of its profit to its members.

Combining the agent's revenue from selling corn to the cooperative (Equation 2.4) and the agent's patronage refund (Equation 2.5), results in revenue from membership in the cooperative:

$$\left(SH_{t}^{i}+X_{t}^{i}\right)\left[\left(CP_{t}+\gamma^{i}\right)+\left(EP_{t}-CP_{t}-CAC\right)\right]. \tag{2.6}$$

2.3.2 Revenue from Outside of the Cooperative

It is possible, but not likely, that an agent will sell all of his corn to the cooperative. In addition, each agent grows soybeans on half of his land and receives revenue from their sale. The agent's net cash flow function must also recognize this revenue.

The quantity of corn sold outside of the cooperative will be the total number of bushels grown less the number of bushels dedicated to the cooperative. If agent i grows corn on $\frac{A^{i}}{2}$ acres and realizes a yield in year t of Y_{t} , then the total number of

[4] It is often the case that an ethanol plant will process non-member corn, but in the case of the cooperative upon which the simulations were modeled these assumptions are true. At any rate, this is a simplifying assumption that does not affect the general conclusions of this study.

bushels the agent will sell outside of the cooperative will be $\left(Y_t \frac{A^i}{2} - (SH_t^i + X_t^i)\right)$.

If $Y_t^i \frac{A^i}{2} - \left(SH_t^i + X_t^i\right) > 0$ then the agent will receive revenue equal to the corn price multiplied by the quantity sold, or $\left[CP_{t+1}\left(Y_t^i \frac{A^i}{2} - (SH_t^i + X_t^i)\right)\right]$. However, if the agent is required to deliver more corn to the cooperative than he actually grows (*i.e.* $Y_t^i \frac{A^i}{2} < \left(SH_t^i + X_t^i\right)$), the agent will incur a small cost for procuring the shortfall and delivering it to the cooperative represented by θ. For simplicity, θ is constant over time and across agents. Therefore, the total revenue from sales of corn outside of the cooperative is captured by the function:

$$\begin{aligned}&\left[(1+\theta)CP_{t+1}\left(Y_t^i A^i - (SH_t^i + X_t^i)\right)\right]\\&where,\ \theta = 0\ if\ \left(Y_t^i A^i - (SH_t^i + X_t^i)\right) \geq 0\\&\qquad \theta = 0.05\ if\ \left(Y_t^i A^i - (SH_t^i + X_t^i)\right) < 0.\end{aligned} \tag{2.7}$$

Assume the agent's soybean yield is Y^S, so his total production of soybeans in time *t* is $Y_t^S \frac{A^i}{2}$. If the market price of soybeans is *BP* then revenue from the sale of soybeans is $BP_t \cdot Y_t^S \frac{A^i}{2}$. However, by assuming the net revenue per acre from soybeans is equal to the net revenue per acre from corn[5], *i.e.* $BP \cdot Y^S \frac{A^i}{2} = CP \cdot Y \frac{A^i}{2}$, then total revenue from sources outside of the cooperative is:

[5] This is a reasonable long-run assumption because if one crop was significantly more profitable than the other, the agent would shift production to the more profitable commodity. In fact, over time the net revenue per acre from growing corn and soybeans tends to be approximately the same. (Lohano 2002).

$$\left[(1+\theta)CP_{t+1}\left(Y_t^i \frac{A^i}{2} - (SH_t^i + X_t^i)\right) + CP_{t+1} \cdot Y_t^i \frac{A^i}{2}\right]. \tag{2.8}$$

2.3.3 Agent Costs

In order to produce corn and soybeans the agent must incur some costs. These costs include operating expenses as well as overhead. In 1999 the average cost of producing corn in Minnesota was $238.82 / acre and the average cost of producing soybeans was $145.92 / acre. (Minn. Agric. Stats.) For an agent who uses half of his land for each crop, his averages production cost would be $192.37 / acre. For simplicity, the average cost of production for each agent in this model is assumed to be C = $200.00/ acre. Agent *i*'s total cost is then:

$$C\ A^i. \tag{2.9}$$

2.3.4 Net Revenue from Trading Shares

Before observing the market prices and yield which determine net cash flow in year *t*, each agent chooses an optimal quantity of cooperative stock to buy or sell. The net change in the number of cooperative shares owned from time *t-1* to *t* is $\left(SH_{t+1}^i - SH_t^i\right) = X_t^i$. If the agent purchases cooperative stock, he must pay the price SP_t for each share[6]. Conversely, if the agent sells stock, he receives SP_t for each share. The net effect on the agent's cash flow from the purchase or sale of stock is then:

$$-SP_t\left(X_t^i\right). \tag{2.10}$$

[6] It is assumed there are no transaction costs associated with buyer or selling shares.

2.3.5 Net Cash Flow Function

Combining revenue from the cooperative (Equation 2.6) and revenue from selling corn on the open market (Equation 2.8), and then subtracting the agent's operating costs (Equation 2.9) and the cost of purchasing cooperative shares (Equation 2.10), agent i's net cash flow function becomes:

$$\Pi_t^i = \left(SH_t^i + X_t^i\right)\left[\left(CP_{t+1} + \gamma^i\right) + \left(EP_{t+1} - CP_{t+1} - CAC\right)\right]$$
$$+\left[\left(1+\theta\right)CP_{t+1}\left(Y_t^i \frac{A^i}{2} - (SH_t^i + X_t^i)\right) + CP_{t+1} \cdot Y_t^i \frac{A^i}{2}\right] - C^i A^i - \left[SP_t\left(X_t^i\right)\right]$$

where θ is defined as in Equation 2.7. Rearranging, removing the agent superscripts, and deleting the time subscripts to reflect an infinite time horizon results in the general NCF function:

$$\begin{aligned} \Pi = {} & (SH + X)\left(EP' - CP' - CAC\right) - \left[SP(X)\right] \\ & + (CP' + \gamma)(SH + X) + \left(1+\theta\right)CP'\left(Y\frac{A}{2} - (SH + X)\right) \qquad (2.11) \\ & - C\frac{A}{2} + CP' \cdot Y\frac{A}{2} - C\frac{A}{2}. \end{aligned}$$

This first line of Equation (2.11) represents the agent's net revenue from ownership in the NGC, the second line is net revenue from the production of corn (including sales of corn to the NGC), and the third line is revenue from the production of soybeans.

2.4 DYNAMICS OF THE ETHANOL AND CORN PRICES

The success of an ethanol cooperative with constant operating costs hinges on the price of its finished good, ethanol, and the price of its input, corn. Understanding the price dynamics of each commodity will, consequently, be critical to constructing realistic simulations and understanding the desirability of the NGC's stock.

This section has two main objectives. The first is to determine the stochastic processes that best describe the ethanol and corn prices. The second is to determine whether it is advisable to create a new price spread variable that is the difference between the price of ethanol and the price of corn. Since the cooperative's profit depends on the difference between the price of ethanol and the price of corn, creating a price spread variable has intuitive appeal. However, after testing for "cointegration" between the corn and ethanol prices I conclude that differencing the two variables would improperly eliminate important trends from the data.

2.4.1 Description of the Data

The price data for this study are taken from Minnesota. The ethanol industry in Minnesota is fairly new. Therefore, long-term data on ethanol prices unavailable. As a result, the data used are annual ethanol prices for the state of Minnesota from 1988 to 2000 (Ye, 2002). For purposes of analysis, all ethanol prices have been converted to 2000 dollars per bushel of corn (using the CPI and a conversion factor of 2.45 gallons of ethanol per bushel of corn), although they are displayed in dollars per gallon to make the results more intuitive. The corn prices are taken from Minnesota Agricultural Statistics and are Minnesota marketing year average prices (adjusted to 2000 dollars). The data for both price processes are presented in Appendix 2.2.

2.4.2 Modeling Ethanol and Corn Prices

2.4.2(a) Testing Different Function Forms

Time series can exhibit different characteristics, including trends and randomness. I will consider three possible processes to describe the corn and ethanol prices. The first possibility is a stationary process:

$$p_t = p_0 + \beta p_{t-1} + \varepsilon_t,\ \beta < 1,\ \varepsilon \sim N(0,\sigma^2) \tag{2.12}$$

that fluctuates randomly around the mean, p_0. The second possibility is a trend-stationary series, which exhibits an upward or downward trend, but deviations from the trend are stationary. For example, in the equation:

$$p_t = \alpha + \beta t + \varepsilon_t \tag{2.13}$$

the trend is determined by $\alpha + \beta t$, while deviations from the trend are determined by the "white noise," ε_t. The third possibility is a non-stationary process, which differs from the previous two in that it does not tend to revert to a mean. A non-stationary process,

$$p_t = \mu + p_{t-1} + \varepsilon_t. \tag{2.14}$$

also called a random-walk, fluctuates stochastically and may or may not trend depending on the value of the intercept term. The non-stationary process is a special case of the stationary process in equation (2.12) where β, the coefficient on the lagged term, is equal to one.

If a time series contains a unit root it is non-stationary and must be differenced at least once in order for it to become stationary. A series of order *d*, denoted *I*(d), has *d* unit roots and must be differenced *d* times before stationarity is achieved. The most common way to test for a unit root is the Dickey-Fuller (DF) method which requires estimating:

$$(p_t - p_{t-1}) = (\gamma - 1)p_{t-1} + \varepsilon_t . \tag{2.15}$$

The null hypothesis of a unit root is $H_0 : \gamma^* = (\gamma - 1) = 0$ against the alternative hypothesis $H_1 : \gamma^* < 0$. The test statistic which is computed from this regression does not have the same distribution of the standard t-statistic, so different critical values derived by Dickey and Fuller must be used.

Estimating Equation (2.15) is an inadequate test of stationarity in many cases. One alternative is to estimate,

$$(p_t - p_{t-1}) = \mu + \gamma^* p_{t-1} + \beta t + \varepsilon . \tag{2.16}$$

The method allows for a constant term and permits testing for a non-stationary process as opposed to a trend-stationary process.[7] Another alternative, when the order of integration, *d*, is unknown is to use the "augmented" Dickey-Fuller test of estimating:

$$(p_t - p_{t-1}) = \mu + \gamma^* p_{t-1} + \beta t + \delta(p_{t-1} - p_{t-2}) + \varepsilon . \tag{2.17}$$

In both Equations (2.16) and (2.17) the null hypothesis of a unit root with no stationary trend (*i.e.* a non-stationary process) is $H_0 : \gamma^* = \beta = 0$.

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[7] As Harris (1995) explains, if the β term were excluded but the true model contained a trend-stationary component the regression could incorrectly set $\gamma^* = 0$ and pick up the trend in the intercept term, μ_t. The addition of the β term prevents this problem.

2.4.2(b) Ethanol Price

The results of econometric tests for a unit root in the ethanol price time series are contained in Appendix 2.3. In regressions of the natural log of the ethanol price with the specifications of Equations 2.15, 2.16 and 2.17, it was not possible to reject the null hypothesis of a non-stationary process. Furthermore, after estimating:

$$(E_t - E_{t-1}) = \mu + \gamma \Delta E_{t-1} + \psi(E_{t-1} - E_{t-2}) + \beta t + \varepsilon$$

I cannot reject the hypothesis that the ethanol price is $I(2)$ [8].

Based on these findings, the augmented model that allows for a second order of integration (Equation 2.17) with $\gamma = \beta = 0$ appears to be the best specification for the ethanol price. Estimating this equation using the natural log of the ethanol price results in:

$$\underset{}{\ln(E_t)} = \underset{(-1.01)}{-0.05} + \ln(E_{t-1}) + \underset{(-1.73)}{-0.70}(\ln(E_{t-1}) - \ln(E_{t-2})) + \varepsilon_t .$$

Neither the intercept nor the coefficient on the second order of integration is significant. Consequently, the dynamics of the ethanol price can be represented by the simple equation,

$$\ln(E_t) = \ln(E_{t-1}) + \varepsilon_t \quad \Rightarrow \quad E_t = E_{t-1} \cdot \varepsilon_t^E \tag{2.18}$$

The error term in 2.18 is assumed to be normally distributed. It has a mean of zero and a variance of 0.023627.

---

[8] The t-statistic on γ is–1.20 and the DF critical value is –4.1.

2.4.2(c) Corn Price

The results of regressions using the natural log of the corn price are also presented in Appendix 2.3. The methods of finding a unit root in this case are identical to those used to analyze the ethanol price. Just as with the ethanol price, I was unable to reject the null hypothesis of a unit root. However, I was able to conclude the corn price was I(1).[9]

Since the corn price is I(1), the proper specification is Equation 2.16 with $\gamma = \beta = \delta = 0$. The corn price process then takes the simple form:

$$\ln(C_t) = \mu + \ln(C_{t-1}) + \varepsilon_t .$$

Estimating this equation:

$$\ln(C_t) = \underset{(-1.23)}{-0.03} + \ln(C_{t-1}) + \varepsilon_t \Rightarrow C_t = C_{t-1} \cdot \varepsilon_t^C \qquad (2.19)$$

The intercept is not significant so the corn price can be represented by a non-stationary process with no significant trend. Again, I assume the error term for the final specification is normally distributed. The residuals have a mean of zero and a variance of 0.027435.[10]

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[9] In a test of $(C_t - C_{t-1}) = \mu + \gamma \Delta C_{t-1} + \psi(C_{t-1} - C_{t-2}) + \beta t + \varepsilon$ I was able to reject the null hypothesis of a unit root, as the t-statistic on γ was –5.14 with a DF critical value of –3.80.

[10] Government price programs have the effect of setting a floor on the corn price farmers will receive. These programs should not affect the price dynamics above that floor, but they could minimize some of the risk of very low corn prices. This model does not take these programs into account.

2.4.3 Cointegration Analysis

2.4.3(a) The Cointegration Issue

The next question is whether it is possible to replace the ethanol price and corn price variables with a stochastic "price spread" variable, denoted $S = EP - CP + \varepsilon^S$. Differencing the ethanol and corn prices could make the model more intuitive and may also make some analytical solutions possible. The danger, however, is that differencing the ethanol and corn prices could have the unintended consequence of either obscuring important relationships between the variables or inferring a relationship where one does not exist.

The method of analyzing this problem is by testing for "cointegration" between the ethanol and corn prices. For example, suppose two time series, x and y, are both $I(1)$, and $z = y + \beta x$. If x and y have independent trends, then one would expect z to be $I(1)$ also. However, if x and y are related so that, for example, they drift together at the same rate, then z may be $I(0)$ (*i.e.* stationary). When z is stationary, x and y are said to be "cointegrated."

The existence of cointegration may be important because a long-run relationship between variables usually implies a long-run equilibrium for the economic system under consideration. (Harris, p.22). Care must be taken because improperly differencing two cointegrated variables may have the unintended effect of washing away this long–run relationship. (Greene, p.790). It may be possible to difference the variables but special econometric methods should be used to capture both the long-run relationship (the equilibrium) and the short-run relationship (the degree of disequilibrium) between them (for a discussion of these methods, see Greene, pp.789-96).

Differencing non-cointegrated variables, on the other hand, can result in a "spurious regression." Regressing one on the other may result in what appears to be a statistically significant relationship, when in fact the regression is merely picking up similar, but unrelated, drifts. While haphazardly differencing two cointegrated variables can obscure relationships between variables, differencing two non-cointegrated variables that suffer from the spurious regression problem can create an illusory relationship.

2.4.3(b) Testing For Cointegration

Initially, it appears that the ethanol and corn price variables are not cointegrated. A linear combination of two series which are integrated to different orders is integrated to the highest of the two orders. (Harris, p. 21). If the corn price is $I(1)$ and the ethanol price is $I(2)$, the difference between them will also be $I(2)$. Then, by definition, the corn and ethanol prices cannot be cointegrated because the difference is not stationary (*i.e.* the difference is not $I(0)$). However, additional analysis is warranted since tests for the order of integration of the ethanol price variable were ambiguous.

The appropriate method to test for cointegration between the corn and ethanol price begins with the model, $\ln(CP_t) = \alpha \ln(EP_t) + R_t$. This is called the "cointegrating regression" and it is estimated using OLS (Greene, p.795). The idea is that if *CP* and *EP* have different trends, then the series of residuals, *R*, will be integrated. However, if *CP* and *EP* are cointegrated, then *R* will be "white noise" and stationary. Testing for cointegration involves generating the residuals from the cointegrating regression and looking for a unit root in those residuals. If a unit root exists, the series are not cointegrated.

The proper specification to test for a unit root is the augmented regression model:

$$(R_t - R_{t-1}) = \mu + \gamma R_{t-1} + \beta t + \delta(R_{t-1} - R_{t-2}) + \varepsilon .$$

The null hypothesis of a unit root is $H_0 : \gamma = 0$ (*i.e.* the residuals are non-stationary and the variables are not cointegrated) against the alternative hypothesis $H_1 : \gamma < 0$. The resulting t-statistic is –1.01 and the DF critical value is -4.1 (Harris, Table A.2, p.156). Furthermore, the F-statistic is 1.91 compared to a DF critical value of 8.65. Therefore, I cannot reject the null hypothesis of a unit root. This result supports the previous conclusion that the ethanol price and corn price are not cointegrated variables.

The implication of finding no cointegration is that inferring a long-term relationship between the corn and ethanol price is likely to be wrong, regardless of how intuitive it may seem. A visual inspection of the data (see Figure 2.1) and a correlation of 0.621 suggest a strong relationship between the corn and ethanol prices, but the cointegration analysis warns that the prices probably exhibit common, but unrelated, trends. Creating a new "price spread" variable may imply a relationship that does not exist and could bias the results of both the agent problem and the market simulations. Consequently, the corn and ethanol prices will be modeled separately according to the specifications Equations 2.18 and 2.19.

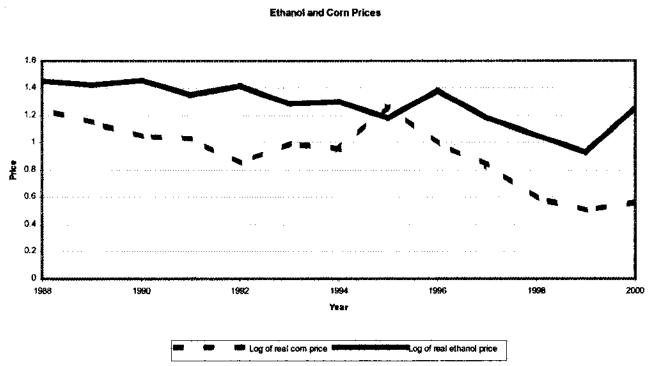

Figure 2.1
Log of Real Ethanol and Corn Prices (1988-2000)

2.5 PRODUCER AND COOPERATIVE CHARACTERISTICS

In this model there are twelve types of agents. Agents may vary by size (A, in the NCF function), by their distance from the cooperative (γ) and by their level of risk aversion (λ). The distribution of these agent types is the same for each of the three market structures under consideration. In addition, the characteristics of the ethanol plant owned by each type of cooperative are identical across NGC types.

To be assured that the parameters are reasonable, it is desirable to create a hypothetical investment setting based on an actual ethanol plant and the population of potential investors that surround it. The seven county area including and surrounding Freeborn County, Minnesota, the home of Exol ethanol cooperative, serves as an empirical basis for this analysis. This geographic area was chosen because most NGC members live within 50 miles of the NGC's ethanol plant (Fruin, p.9). The presence of ethanol plants approximately 100 miles to either side of Exol also suggest that Freeborn County and the six contiguous countries are an appropriate geographic area from which to model a pool of potential investors. The relevant statistics about the characteristics of the farms in those counties is contained in Appendix 2.4 and will form the basis for the discussion to follow.

2.5.1 Agent Characteristics

There are three farm sizes in this model: small (300 total crop acres), medium (600 total crop acres) and large (1200 total crop acres). In Southern Minnesota, most producers grow both corn and soybeans, which is why the model assumes a 50-50 allocation of corn and soybeans for each agent.

The average corn yield and yield variance in the model area from 1988 to 2000 is shown in Table 2.1 . Using these statistics as a guide, the model employs a mean yield parameter of 140 bu./acre and a yield variance of 475.

County	**Ave. Corn Yield (bu. / acre)**	**Corn Yield Variance**
Freeborn	134.1429	459.6703
Contiguous Counties	134.1214	519.3203
	Correlation: 0.967227	
Source: *Agricultural Historical Statistics (NASS)*		

Table 2.1
Average Corn Yield And Variance

In 1997, Freeborn County and the six contiguous counties were the home of 4234 farms that grew corn. Approximately 68 percent of these farms were between 50 and 499 acres in size, 22 percent were 500 to 1000 acres, and 10 percent were greater than 1000 acres. In the simulations for each of the NGC types, the population of agents is distributed among small, medium and large producers in approximately these proportions.

The number of farms growing corn in the counties surrounding Freeborn County outnumber those in Freeborn County by approximately 4 to 1. Agents in the surrounding counties are designated as "far" agents because they incur a $0.10 /bushel transportation cost to deliver corn to the ethanol plant. In other words, γ^j is equal to -$0.10 for "far" agents and zero otherwise.

The coefficients of risk aversion (λ) used in the model are given in Table 2.2.

Farm Size	High Risk Aversion	Low Risk Aversion
300 acres	$\lambda = 0.000015$	$\lambda = 0.000004$
600 acres	$\lambda = 0.000008$	$\lambda = 0.000002$
1200 acres	$\lambda = 0.000002$	$\lambda = 0.0000005$

Table 2.2
Risk Aversion Coefficients

A risk neutral agent would have a certainty equivalent equal to the mean value of a 50/50 lottery. The parameters of the model were chosen so that agents with low risk aversion have certainty equivalents approximately equal to 90% of the agent's expected return and agents with high risk aversion have certainty equivalents approximately equal to 65% of expected returns. There is no reliable way to characterize the level of risk aversion for farmers in the model counties, so it is assumed that half of each type of agent are highly risk averse, half are slightly risk averse.

The characteristics of the agents in the model's pool of hypothetical investors have been distributed to reflect the population of farms in Freemont and its surrounding counties. Specifically, the agent types used in each simulation model were chosen to match the distribution in Table 2.3 as closely as possible.

Agent Type	**Overall Percentage In The Population**
Large	10
Medium	22
Small	68
Near	20
Far	80
Highly Risk Averse	50
Slightly Risk Averse	50

Table 2.3
Distribution of Agent Types

2.5.2 Ethanol Plant Characteristics

The Exol plant located in Albert Lea, Minnesota can produce 36 million gallons of ethanol per year with 13 million bushels of corn.[11] The initial cost of an ethanol plant of this size is reported to be approximately $97 million. Assuming half the cost of the plant is financed with equity (usually 40 to 60 percent of the cost of a

[11] This conversion rate is approximately 2.75 gallons / bushel, which is slightly higher than the generally accepted range of 2.4 to 2.6 and higher than the conversion rate of 2.45 used in the model.

plant is financed with equity), the initial equity required to build the plant is $48.5 million. If the cooperative issues 13 million shares, each representing the right and obligation to deliver one bushel of corn each year, the share price required to raise $48.5 million is $3.73. The initial share price used in the model to determine investment thresholds is $3.75.

Estimates of the operating costs of an ethanol plant can vary significantly. Some plant feasibility studies estimate the cost to process a bushel of corn to be in excess of $2.10, while a recent study by Tiffany (2003) suggests the cost is about $1.70 per bushel of corn. This model assumes an operating cost of $2.00 per bushel of corn processed. Until very recently, the State of Minnesota subsidized the production of ethanol at a rate of $0.20 per gallon up to $3,000,000. On a bushel basis, the state production subsidy assumed by this model is $0.21 per bushel of corn processed.

2.5.3 Simulation Structure

Investment decisions under each organizational structure are simulated fifty times over ten-year periods for randomly generated scenarios that are defined by values of all the random variables in the model. This analysis yields detailed information on investment and disinvestments for the IOF structure and on trade volumes, share prices, and the distribution of membership for the two NGC structures.

Since a computer simulation with 4200 agents and 13 million shares would be far too large to run in any reasonable length of time, the number of agents and the number of shares available were both scaled back by either a factor of 0.005 or a factor of 0.01. The smaller scale was used for preliminary simulations primarily used to estimate relevant model parameters and the larger scale was used for analysis. If the scale factor is 0.005, the simulations involve twenty-one agents and 65,000 shares available for purchase from the cooperative. When the scale factor is 0.01, there are forty-two agents and 130,000 shares available. Testing showed that the share price dynamics are robust to changes in the scale factor[12].

[12] Simulations using identical corn and ethanol prices were performed using various scale factors. The resulting share prices were the same in every case.

APPENDIX 2.1

Summary of Parameters for Agent Optimization Problem

Parameter	Description	Value
A	Number of crop acres on a farm	300 / 600 / 1200 acres
C	Producer's average cost per bushel of production	$200 / acre
CAC	Cooperative's average cost per bushel of processing (is the cooperative's average cost less the ethanol subsidy)	$2.00 / bu. - $0.21 / bu. = $1.79 / bu.
r	Interest rate	0.03
Y	Corn yield	Mean: 140 bu./acre Var: 475
β	Discount factor = $\frac{1}{1+r}$	0.97
λ	Risk aversion parameter	See Table 2.4
γ	Price difference variable for farms of different distances from the cooperative	-$0.10 / $0
θ	The cost of acquiring and delivering a corn shortfall to the cooperative	5%
	Factor for converting corn to ethanol	2.45 gallons / bushel

APPENDIX 2.2

Ethanol and Corn Price Data

Year	CPI (2000 = 100), All urban Consumers, U.S. City Average, All Items	Nominal Corn Price (MN Marketing year average price, $/bu.)	Real Corn Price (2000 $'s)	Nominal Ethanol Price (MN annual average, $/gal)	Real Ethanol Price (2000 $'s)	Adjusted, Real Ethanol Prices
2000	100.00	1.75	1.75	1.43	1.43	3.50
1999	96.75	1.60	1.65	1.00	1.03	2.53
1998	94.66	1.71	1.81	1.11	1.17	2.87
1997	93.21	2.15	2.31	1.24	1.33	3.26
1996	91.11	2.47	2.71	1.48	1.62	3.98
1995	88.50	3.14	3.55	1.18	1.33	3.27
1994	86.06	2.23	2.59	1.29	1.50	3.67
1993	83.91	2.26	2.69	1.24	1.48	3.62
1992	81.48	1.91	2.34	1.37	1.68	4.12
1991	79.09	2.22	2.81	1.25	1.58	3.87
1990	75.90	2.17	2.86	1.33	1.75	4.29
1989	72.01	2.27	3.15	1.22	1.69	4.15
1988	68.70	2.40	3.49	1.20	1.75	4.28
	Source: *U.S. Dept. of Labor, Bureau of Labor Statistics*	***Source:*** *Minnesota Agricultural Statistics (various years)*		***Source:*** *Ye, "Economic Impact of the Ethanol Industry in Minnesota (2002)*		

APPENDIX 2.3

Summary of Regression Results for Ethanol and Corn Price Specifications

Ethanol Price Analysis				
Model	Null Hypothesis	Test Statistic	Critical values (at 0.025)	Conclusions
Equation 2.15: $(E_t - E_{t-1}) = \mu + \gamma E_{t-1} + \varepsilon$	$\gamma = 0$	$\tau_\gamma = -1.88$	DF = -3.4[i]	Cannot reject the null, so conclude a unit root exists and the price of ethanol is non-stationary
Equation 2.16: $(E_t - E_{t-1}) = \mu + \gamma E_{t-1} + \beta t + \varepsilon$	$\gamma = 0$	$\tau_\gamma = -3.75$	DF = -4.1	Cannot reject the null using DF critical values.
	$\gamma = \beta = 0$	$F = 7.29$	DF = 8.65[ii]	Cannot reject the null. Suggests the time trend is not significant under the null of a unit root.[iii]
Equation 2.17: $(E_t - E_{t-1}) = \mu + \gamma E_{t-1} + \beta t + \delta(E_{t-1} - E_{t-2}) + \varepsilon$.	$\gamma = 0$	$\tau_\gamma = -3.01$	DF = -4.1[iv]	Cannot reject the null using DF critical values, but do reject the null using the standard t statistic.
	$\gamma = \beta = 0$	$F = 4.80$	DF = 8.65	Cannot reject the null. Suggests the time trend is not significant under the null of a unit root.

Corn Price Analysis				
Model	Null Hypothesis	Test Statistic	Critical Values at 0.025	Conclusions
Equation 2.15: $(C_t - C_{t-1}) = \mu + \gamma C_{t-1} + \varepsilon$	$\gamma = 0$	$\tau_\gamma = -1.01$	DF = -3.22[v]	Cannot reject the null, so conclude a unit root exists and the price of ethanol is non-stationary
Equation 2.16: $(C_t - C_{t-1}) = \mu + \gamma C_{t-1} + \beta t + \varepsilon$	$\gamma = 0$	$\tau_\gamma = -2.55$	DF = -3.80	Cannot reject the null using DF critical values.
	$\gamma = \beta = 0$	$F = 3.31$	DF = 7.81[vi]	Cannot reject the null. Suggests the time trend is not significant under the null of a unit root.
Equation 2.17: $(C_t - C_{t-1}) = \mu + \gamma C_{t-1} + \beta t + \delta(C_{t-1} - C_{t-2}) + \varepsilon$.	$\gamma = 0$	$\tau_\gamma = -2.83$	DF = -3.80	Cannot reject the null using DF critical values.
	$\gamma = \beta = 0$	$F = 2.70$	DF = 7.81	Cannot reject the null. Suggests the time trend is not significant under the null of a unit root.

[ii] Greene, Table 18.5, p.783.
[ii] Harris, Table A.2, p.156.
[iii] Harris, p.31.
[iv] Harris says to use the critical values from the non-augmented model (p.34).
[v] Greene, Table 18.5, p.783.
[vi] Harris, Table A.2, p.156.

APPENDIX 2.4

Characteristics of Freeborn County and Its Contiguous Counties

	Freeborn	Faribault	Mower	Steele	Waseca	Worth	Winnebago
Farms planting corn	780	735	799	515	534	433	438
Acres of corn	166,520	198,827	169,284	96,425	103,034	102,966	118,378
Bushels of corn	23,788,926	28,537,415	24,333,069	13,164,908	14,570,926	14,324,472	16,976,038
Ave acres / farm	213.49	270.51	211.87	187.23	192.95	237.80	270.27
Ave. bu / farm	30,498.62	38,826.41	30,454.40	25,562.93	27,286.38	33,081.92	38,758.08
Total number of farms	1,151	878	1,123	774	709	608	607
Percent 1 to 9 ac	0.08	0.05	0.07	0.07	0.06	0.07	0.09
Percent 10 to 49	0.17	0.08	0.14	0.17	0.13	0.13	0.12
Percent 50 to 179	0.25	0.16	0.28	0.30	0.28	0.24	0.21
Percent 180 to 499	0.26	0.36	0.28	0.30	0.30	0.26	0.30
Percent 500 to 999	0.16	0.24	0.15	0.10	0.16	0.22	0.19
Percent 1000 +	0.08	0.11	0.08	0.05	0.07	0.08	0.09

Source: 1997 Census of Agriculture

CHAPTER 3

WAITING AND DIVERSIFICATION AS RESPONSES TO RISK

3.1 INTRODUCTION

There are many ways to alleviate the impact of risk. In this model, an agent facing volatile corn prices and uncertain returns from investment in a NGC has two main tools at his disposal. The first is to wait. An agent who is unsure about how much to invest in a NGC because of uncertainty over future corn, ethanol and share prices can simply wait to see what happens and make a more informed decision based on this additional information. His second tool is diversification. If the returns from selling corn and investing in a NGC are not highly correlated, an agent might reduce his overall level of risk by not "putting all of his eggs in one basket." This chapter will explore the impacts of both of those risk management strategies on the demand for shares of a new generation cooperative.

3.2 WAITING AS A RESPONSE TO RISK

There is no option to wait in a static problem. The traditional rule that an agent should invest when the marginal net present value exceeds the marginal cost is based on a static analysis and, consequently, ignores the value of waiting. Assessing the value of waiting, then, requires the formation and solution of a dynamic problem. The approach taken in this section is to solve two simple dynamic programming problems and identify the set of states at which investment first occurs (the "investment threshold"). The value of waiting can then be determined by comparing the dynamic investment thresholds to their corresponding NPV thresholds.

The next two subsections derive analytical solutions to two highly simplified versions of the agent problem. The first problem is one of a risk-neutral agent, where the agent's share balance enters into the utility function in a linear fashion. This example is the cleanest illustration of how using a real options approach to the agent problem differs from the traditional "net present value" rule of investment, and will be particularly helpful to analyzing the IOF's problem. In the second example, the agent's share balance enters into the utility function in a non-linear way, as it would in the case of a risk-averse agent. This example is intended to show that adding some convexities to the problem make incremental investment an optimal strategy and is useful in predicting the impact of changes in the degree of convexity (*i.e.* the level of risk aversion). After these investment thresholds are derived analytically the value of waiting will be assessed.

3.2.1 Analytical Solution in the Case of a Linear Utility Function

In these simple examples the only stochastic variable is the cooperative's single period profit, $P' = P + \varepsilon^P$, $\varepsilon^P \sim N(0, \sigma^2)$. Assuming the agent has no income outside of the cooperative, his net cash flow function is: $\Pi = SH' \cdot P - SP \cdot X$. In continuous time, the Bellman equation is:

$$W(SH',P) = \max_X \left\{ \mathrm{E}\left[(SH' \cdot P)dt - SP \cdot X\right] + e^{-\rho dt}\mathrm{E}\left[W(SH', P + dP)\right]\right\}$$

subject to:

$$\begin{aligned} &P + dP = P + \varepsilon_t^P \\ &SP = g(P, SP_{-1}, SH, X, \varepsilon^S) \\ &SH' = SH + X \\ &0 \le SH' \le SH_{\max} \end{aligned} \tag{3.1}$$

The goal is to determine the boundary between the states in which positive investment is optimal and those where disinvestment is optimal. This boundary is the "investment threshold" and is the set of points where the optimal policy is to trade nothing – *i.e.* the set of points where *SH'=SH.*

The first step is to solve the Bellman equation for the value function, $W(SH', P)$. This is complicated by the fact that *P* moves stochastically and does not have a derivative. Therefore, the right side of (3.1) must be expanded using Ito's Lemma:

$$\mathrm{E}[dW] = \frac{1}{2}\sigma^2 W_{PP}dt$$

where $W_{PP} = \frac{\partial^2 W}{\partial P^2}$ (See Appendix 3.1). By substituting this result into Equation (3.1), and recognizing that $\mathrm{E}[P] = P$ and $X = 0$ at the investment threshold,

$$W(SH',P) = (SH' \cdot P)dt + e^{-\rho dt}\left[W(SH',P) + \frac{1}{2}\sigma^2 W_{PP}dt\right]$$

$$W(SH',P) = W(SH',P) + (SH' \cdot P)dt - \rho dt W(SH',P) + \frac{1}{2}\sigma^2 W_{PP}dt$$

Rearranging and dividing through by *dt* yields,

$$SH'\cdot P - \rho W(SH',P) + \frac{1}{2}\sigma^2 W_{PP} = 0. \qquad (3.2)$$

Equation 3.2 is a partial differential equation which $W(SH',P)$ must satisfy. Dixit and Pindyck show the general solution to (3.2) is:

$$W(SH',P) = A_1(SH')P^{\beta_1} + A_2(SH')P^{\beta_2} + \frac{SH'\cdot P}{\rho} \qquad (3.3)$$

where A_1 and A_2 are functions of SH' to be determined and β_1 and β_2 are roots of the fundamental quadratic.

Dixit and Pindyck also explain how the A_2 term in Equation (3.3) can be eliminated using economic intuition. When $P \to 0$, $A_2 P^{\beta_2} \to \infty$ since $\beta_2 < 0$. However, the value function should not be infinite when the cooperative has zero economic profit, so A_2 must be zero. Therefore,

$$W(SH',P) = A_1(SH')P^{\beta_1} + \frac{SH'\cdot P}{\rho}. \qquad (3.4)$$

The second term on the right side of Equation 3.4 is the expected discounted marginal revenue of NGC stock. In other words, it is the value of maintaining the *status quo* indefinitely. The first term on the right is then the value of the option to change one's stock holdings in the future. To fully understand the magnitude of these terms it is necessary to solve for *P* and A_1.

Two "boundary conditions" are required to solve for *P*. These can be obtained by taking the first-order condition of the Bellman equation:

$$W_X(SH',P) = \mathrm{E}[Pdt - SP] + e^{-\rho dt}\mathrm{E}[W_X(SH',P+dP)] = 0$$

and then letting $dt \to 0$:

$$(P - SP) + W_X(SH, P') = 0$$

$$W_X(SH, P') = (SP - P). \qquad (3.5)$$

where $W_X = \dfrac{\partial W}{\partial X}$. In Equation 3.5, the term on the left is the marginal value of investment and the term on the right is the marginal cost. The marginal cost is the expense of purchasing a share less the revenue obtained from the right to sell corn to the cooperative.

The first boundary condition is called the "value-matching" condition. The value-matching condition sets the unknown function, *W(SH',P)*, equal to a known function. In this case, Equation 3.5 does just that. Combining Equation 3.5 with the derivative of the expression for the value function (Equation 3.4) yields the value-matching condition:

$$A_X P^{\beta_1} + \frac{P}{\rho} = (SP - P). \qquad (3.6)$$

where $A_X = \dfrac{\partial A_1}{\partial X}$.

The second boundary condition is the "smooth-pasting" condition. This is a technical requirement that the functions comprising the value-matching condition, W_X and *(SP-P)*, meet tangentially at the boundary. (Dixit and Pindyck, p.130). Taking the derivative of each side of Equation 3.6 with respect to *P* yields the smooth-pasting condition:

$$\beta_1 A_X P^{\beta_1 - 1} + \frac{1}{\rho} = -1 \qquad (3.7)$$

Finally, solving the value-matching condition for A_X and substituting the answer into (3.7) results in the investment threshold for the risk-neutral agent:

$$P^* = \frac{\beta_1}{(\beta_1 - 1)} \frac{SP\rho}{(\rho + 1)} \quad . \tag{3.8}$$

Using (3.7) and (3.8):

$$A_X = -\left[\frac{\rho+1}{\beta_1\rho}\right]^{\beta_1}\left[\frac{\beta_1 - 1}{SP}\right]^{\beta_1 - 1} \quad . \tag{3.9}$$

Solving for A_1:

$$A_1 = \int_X^\infty - A_X dX = \left[\frac{\rho+1}{\beta_1\rho}\right]^{\beta_1}\left[\frac{\beta_1 - 1}{SP}\right]^{\beta_1 - 1} X \, . \tag{3.10}$$

The importance of Equation 3.9 is that $A_X < 0$. Increasing investment decreases A_1, which in turn decreases the value of holding the option to invest in the future (the first term of Equation 3.4). This is merely a reflection that increasing investment has the corresponding cost of giving up the option to invest. To see this more clearly, rearrange the value-matching condition:

$$P + \frac{P}{\rho} = SP - A_X P^{\beta_1} \, .$$

The left side of this expression is the discounted expected revenue over an infinite horizon. The first term on the right is the marginal cost of a share and the second term on the right is the marginal opportunity cost of holding the option to invest (*i.e.* the value of waiting). The inclusion of the second term, which is negative, implies that the *true* marginal cost of investment is higher than it would be if the opportunity cost of relinquishing the option to invest were not taken into account.

3.2.2 Analytical Solution in the Case of a Convex Utility Function

An agent's optimal level of investment will be either the minimum or maximum number of shares allowed unless there is some convexity in the agent's problem. One way that this type of convexity might appear is through a utility function. To see what happens when the NCF function enters into the problem non-linearly, consider the simple case of:

$$U(\Pi) = (SH' \cdot P)^{\lambda} - SP \cdot X \tag{3.11}$$

This is a utility function that exhibits constant relative risk aversion (CRRA)[1]. It is assumed $0 < \lambda \leq 1$, and risk aversion increases (*i.e.* the risk premium increases) as λ decreases. When numerical solutions are found the net revenue from trading shares is also included in the utility function, but doing so here would complicate the math and obscure the main conclusions.

When the utility function takes the form of Equation 3.11, the Bellman equation becomes:

$$W(SH', P) = \max_{X}\left\{\mathrm{E}\left[(SH' \cdot P)^{\lambda} dt - SP \cdot X\right] + e^{-\rho dt}\mathrm{E}\left[W(SH', P + dP)\right]\right\}$$

subject to:

$$\begin{aligned} &P + dP = P \cdot \varepsilon_t^P \\ &SP = g(P, SP_{-1}, SH, X, \varepsilon^S) \\ &SH' = SH + X \\ &0 \leq SH' \leq SH_{\max} \end{aligned} \tag{3.12}$$

Setting $X = 0$ and expanding using Ito's Lemma yields:

$$(SH' \cdot P)^{\lambda} - \rho W(SH', P) + \frac{1}{2}\sigma^2 W_{PP} dt = 0$$

[1] The shift from a utility function exhibiting constant absolute risk aversion to the CRRA function is done solely to keep the algebra manageable. It does not change the general conclusions of this section.

with the solution to the value function being:

$$W(SH',P) = B(SH')P^{\beta_1} + \frac{(SH' \cdot P)^{\lambda}}{\rho}.$$

Using the methods of the previous section, the value-matching condition becomes:

$$P\lambda(SH' \cdot P)^{\lambda-1}\left(\frac{\rho+1}{\rho}\right) + B_X P^{\beta_1} = SP$$

and the smooth-pasting condition is:

$$\lambda^2 (SH' \cdot P)^{\lambda-1}\left(\frac{\rho+1}{\rho}\right) + \beta_1 B_X P^{\beta_1 - 1} = 0.$$

Solving the value-matching condition for B_X, substituting into the smooth-pasting condition, and solving for P^*, results in the investment threshold:

$$P^* = \left[\frac{\beta_1}{\lambda(\beta_1 - \lambda)} \frac{SP\rho}{(\rho+1)(SH+X)^{\lambda-1}}\right]^{\frac{1}{\lambda}}. \qquad (3.13)$$

An increase in the share balance will result in an increase in the investment threshold since $\frac{\partial P^*}{\partial SH} > 0$. This is because the introduction of the convex utility function results in decreasing marginal utility for shares of the cooperative. The result is that the optimal share balance will be $0 < SH < SH_{\max}$ (i.e. incremental investment will be optimal).

Contrast this result with the linear utility function example. In the risk-neutral example A_1 was linearly increasing in X (Equation 3.10) and the value function (Equation 3.4) was also linearly increasing in X. This implies that when the investment promises a positive benefit a risk-neutral agent can increase the value function infinitely by continuing to increase investment in the NGC. When the investment is not favorable, the optimal policy for a risk-neutral agent is to sell all of his NGC shares. When the utility function exhibits some convexity, however, the agent must balance the benefit of owning shares in the NGC and his divergent interest in holding the option to purchase shares in the future.

3.2.3 The Value of Waiting

Comparisons of the investment thresholds in these two examples with their respective NPV thresholds reveals the magnitude of the value of waiting. In the risk-neutral case, application of the NPV investment rule results in the following investment threshold[2] :

$$P = \frac{SP \cdot \rho}{(\rho + 1)}.$$

The investment threshold in Equation 3.8 exceeds this NPV threshold by a factor of

$\frac{\beta_1}{(\beta_1 - 1)} > 1$. The real options approach recognizes that the marginal cost of an investment includes the lost value of waiting for uncertainty to be resolved, and consequently the marginal benefit must be higher before investment will take place.

In the case of a convex utility function, the NPV rule threshold is[3]:

---

[2] In this case, $NPV = SH' \cdot P + \frac{SH' \cdot P}{\rho}$. The marginal NPV is $NPV_X = P + \frac{P}{\rho} = P\left(\frac{\rho+1}{\rho}\right)$. Set this equal to the marginal cost, and the NPV investment rule becomes, $P = \frac{SP \cdot \rho}{(\rho+1)}$.

[3] The net present value of a share in this case is $NPV = (SH' \cdot P)^{\lambda} + \frac{(SH' \cdot P)^{\lambda}}{\rho}$. Setting the marginal NPV equal to marginal cost and solving for P results in the NPV threshold.

$$P^{NPV} = \left[\frac{SP\rho}{(\rho+1)SH'^{\lambda-1}} \right]^{\frac{1}{\lambda}}.$$

This time, the real options threshold exceeds the NPV threshold by a factor of:

$$\left[\frac{\beta_1}{\lambda(\beta_1 - \lambda)} \right]^{\frac{1}{\lambda}} > 1.$$

Notice that if $\lambda = 1$ this factor becomes $\frac{\beta_1}{(\beta_1 - 1)}$, which is the result we get in the risk neutral case.

Risk aversion has an influence on the investment threshold. Taking the partial derivative of (3.13) with respect to λ results in $\frac{\partial P^*}{\partial \lambda} < 0$ so long as $\lambda < \beta_1$. Recall that β_1 is the larger root of the fundamental quadratic equation, so in this case $\beta_1 = \frac{1}{2} + \sqrt{\frac{1}{4} + \frac{2\rho}{\sigma^2}} > 1$. Since $0 < \lambda \leq 1$ it is always the case that $\lambda < \beta_1$. In other words, a higher level of risk aversion increases the value of waiting and increases the investment threshold.

The final point is that the value of waiting increases as the level of uncertainty increases. As σ^2 increases β_1 decreases, which implies that in the risk-neutral case $\frac{\beta_1}{(\beta_1 - 1)}$ increases and the investment threshold increases. The same holds true when $\lambda < 1$.

3.3 DIVERSIFICATION AS A RESPONSE TO RISK

In the simple dynamic programming problems in the previous section analytical solutions were possible only because the Bellman equations contained a single stochastic variable. Other sources of investment were ignored and, consequently, the potential for diversification was also ignored. In this section, there are two stochastic variables, the ethanol and corn prices. The agent can purchase shares in a NGC, which requires delivery of an equivalent number of bushels of corn, or he can sell his corn on the open market. Using methods described by Robison and Barry (1987) a simple one-period certainty-equivalent model is solved in order to examine how the desire to diversify affects the optimal level of investment in a new generation cooperative.

3.3.1 The Optimal Level of Diversification

Robison and Barry explain that the optimal level of diversification can be determined by maximizing the certainty equivalent. Pratt (1964) showed that an individual's certainty equivalent can be expressed as:

$$CE(y) = E[y] - \frac{1}{2} R(y)\sigma^2$$

where *R(y)* is the absolute risk aversion function. For a negative exponential utility function, $R(y) = \lambda$.[4] Therefore, an agent's optimal level of diversification is defined by:

$$\max_{X} CE(EP, CP) = E[\Pi] - \frac{\lambda}{2}\sigma^2(\Pi) \qquad (3.14)$$

---

[4] R(y) is defined as $-U''(y)/U'(y)$. For the negative exponential, $R(y) = -\left(-\lambda^2 e^{-\lambda y} / \lambda e^{-\lambda y}\right) = \lambda$.

where $\sigma^2(\Pi)$ is the variance of the NCF function, Π.

To make this example more transparent, I will begin by simplifying the NCF function described in Chapter 2. For purposes of this example, the revised NCF function is:

$$\Pi = (Y - SH - X)CP + (SH + X)[CP + (EP - CP - CAC)] - C - X \cdot SP.$$

The yield is assumed to be determinate so Y represents the total output of corn, C is the farm's total cost of production, and SP is the cost of acquiring a share of the NGC. All other variables have the same meaning as in Equation 2.11. For simplicity the income from soybeans and the impact of distance have been ignored.

To solve Equation 3.14, it is necessary to determine the expected value and variance of the net cash flow function. The agent's expected net cash flow is,

$$\mathrm{E}[\Pi] = \mathrm{E}[CP](Y - SH - X) + \mathrm{E}[EP](SH + X) - CAC(SH + X) - C - X \cdot SP.$$

Since $CP = CP_{-1}\exp(\varepsilon^C)$, $\varepsilon^C \sim N(0, \sigma^2_{\varepsilon_C})$ and

$EP = EP_{-1}\exp(\varepsilon^E)$, $\varepsilon^E \sim N(0, \sigma^2_{\varepsilon_E})$,

$$\mathrm{E}[CP] = CP_{-1}\mathrm{E}[\exp(\varepsilon^C)] = CP_{-1}\exp\left(\sigma^2_{\varepsilon^C}/2\right) = \mu_C, \text{ and}$$

$$\mathrm{E}[EP] = EP_{-1}\mathrm{E}[\exp(\varepsilon^E)] = EP_{-1}\exp\left(\sigma^2_{\varepsilon^E}/2\right) = \mu_E.$$

(Law and Kelton, 1982, p.164-65).

The variance of the net cash flow function is:

$$Var(\Pi) = (Y - SH - X)^2 Var[CP] + (SH + X)^2 Var[EP] + 2(Y - SH - X)(SH + X)\sigma_{EC}$$

where, σ_{EC} is the covariance of the ethanol and corn prices which, in this model, is assumed to be equal to zero. The variance of the corn and ethanol prices are:

$$Var[CP] = Var(CP_{-1}\exp(\varepsilon^{C})) = CP_{-1}^{2}Var[\exp(\varepsilon^{C})] = CP_{-1}^{2}e^{\sigma_{\varepsilon C}^{2}}(e^{\sigma_{\varepsilon C}^{2}} - 1) = \sigma_{C}^{2}$$

and

$$Var[EP] = EP_{-1}^{2}e^{\sigma_{\varepsilon E}^{2}}(e^{\sigma_{\varepsilon E}^{2}} - 1) = \sigma_{E}^{2}.$$

(Law and Kelton, 1982, p.164-65). Therefore, the variance of the NCF function can be written:

$$Var(\Pi) = (Y - SH - X)^{2}\sigma_{C}^{2} + (SH + X)^{2}\sigma_{E}^{2}.$$

Substituting the expressions for the expected value and variance of the net cash flow function into Equation 3.14 results in:

$$CE(CP, EP) = \mu_{C}(Y - SH - X) + \mu_{E}(SH + X) - CAC(SH + X) - C - X \cdot SP - \frac{\lambda}{2}\left[(Y - SH - X)^{2}\sigma_{C}^{2} + (SH + X)^{2}\sigma_{E}^{2}\right]$$

Differentiating with respect to X yields the first-order condition[5]:

$$-\mu_{C} + \mu_{E} - CAC - SP - \frac{\lambda}{2}\left[-2(Y - SH - X)\sigma_{C}^{2} + 2(SH + X)\sigma_{E}^{2}\right] = 0.$$

Solving for X and simplifying gives the optimal number of shares in the NGC which the agent will purchase or sell:

$$X^{*} = (\sigma_{E}^{2} + \sigma_{C}^{2})^{-1}\left[\frac{\mu_{E} - \mu_{C} - CAC - SP}{\lambda} + Y\sigma_{C}^{2}\right] - SH \qquad (3.15)$$

[5] The second-derivative condition for a maximum, $-\lambda\left(\sigma_{C}^{2} + \sigma_{E}^{2}\right) < 0$ is also satisfied.

Since investment in a NGC acts to blunt the effect of corn price volatility, Equation 3.15 is also a measure of the agent's optimal level of diversification.

3.3.2 The Effect Of Diversification On The Investment Threshold

The most significant feature of the value of waiting is that it drives an agent's investment threshold above the net present value threshold. An important question then is whether the opportunity to diversify reinforces or counteracts the impact of the value of waiting.

The single year net revenue from a share in the NGC is represented in Equation 3.15 by $\mu_E - \mu_C - CAC - SP = \pi(\sigma_E^2, \sigma_C^2)$. Initial investment in the NGC is positive if $X^* > 0$ when $SH = 0$. As a result, the agent will have positive initial investment when:

$$(\sigma_E^2 + \sigma_C^2)^{-1}\left[\frac{\pi}{\lambda} + Y\sigma_C^2\right] > 0.$$

Solving for π creates the condition under which an agent will initially invest in the cooperative:

$$\pi > -(Y\sigma_C^2\lambda).$$

On the threshold, this expression is satisfied with equality. All of the terms on the right side are positive, so an agent's desire to diversify will lead him to invest in the NGC even when the single period net revenue from the cooperative is negative. The NPV threshold always involves a positive NGC profit, so the impact of diversification is to drive the investment threshold down, contrary to the effect of the value of waiting. Solving the agent's problem numerically is the only way to determine which effect is stronger.

The benefit of diversification, and consequently the demand for NGC shares, is affected by changes in the corn and ethanol price. The overall impact of price changes depends on how an agent balances his desire for higher income against his need for risk reduction. To see these competing effects, consider the impact on the optimal level of NGC investment from a change in the observed (previous period) corn price:

$$\frac{\partial X^*}{\partial CP_{-1}} = \left[\left(\frac{\partial \sigma_C^2}{\partial CP_{-1}}\right)\frac{Y\sigma_E^2 - \pi/\lambda}{(\sigma_E^2 + \sigma_C^2)^2}\right] + \left[\left(\frac{\partial \pi}{\partial CP_{-1}}\right)\frac{1}{\lambda(\sigma_E^2 + \sigma_C^2)}\right] \quad (3.16)$$

The first term on the right is positive when $\pi < (Y\sigma_E^2\lambda)$. This is the case for all of the states on the investment threshold since $(Y\sigma_E^2\lambda) > 0$ and $\pi = (Y\sigma_C^2\lambda) < 0$ on the threshold. The second term on the right is unambiguously negative. Therefore, the overall impact of a change in the corn price depends on the relative magnitude of these terms.

The first term in (3.16) is the "risk-reduction effect" and it represents the positive impact on NGC investment from the desire to minimize the additional risk of a higher corn price. A higher corn price in the previous time period implies a higher variance in the current period. The variance of the return from the cooperative is:

$$Var[EP - CP - CAC - SP] = Var[EP - CP] = \sigma_E^2 + \sigma_C^2.$$

Therefore, as σ_C^2 increases and σ_E^2 remains fixed, the variance of the return from the NGC decreases relative to the risk of selling corn on the market. This, in turn, prompts the agent to increase his investment in the NGC.

The second term in Equation 3.16 is the "income effect" and it represents the negative impact on the NGC's profit from an increase in the corn price. When the previous period's corn price is high, the expected corn price in the current period is even higher (section 3.3.1). This reduces the NGC's expected profit and decreases demand for NGC shares.

The effect of a change in the observed ethanol price is exactly opposite:

$$\frac{\partial X^*}{\partial EP_{-1}} = \left[\left(\frac{\partial \pi}{\partial EP_{-1}}\right)\frac{1}{\lambda(\sigma_E^2 + \sigma_C^2)}\right] + \left[-\left(\frac{\partial \sigma_E^2}{\partial EP_{-1}}\right)\frac{Y\sigma_C^2 + \pi/\lambda}{(\sigma_E^2 + \sigma_C^2)^2}\right]$$

The first term on the right is the effect of the ethanol price on NGC profit, and it is positive. The second term is negative and it represents the effect of the relative increase in the variance of the return on the NGC shares that results from an increase in the variance of the ethanol price.

The final question is the impact of risk aversion on diversification.

$$\frac{\partial X^*}{\partial \lambda} = -\lambda^{-2}\left[\frac{\pi}{\sigma_E^2 + \sigma_C^2}\right] \quad \begin{aligned} &> 0 \; if \; \pi < 0 \\ &< 0 \; if \; \pi > 0 \end{aligned}$$

When the cooperative is profitable, an agent with higher risk-aversion will demand more diversification and have a lower investment threshold than his less risk averse counterpart. On the other hand, when the cooperative is providing a negative return an agent with lower risk aversion will be more eager to invest.

3.4 CONCLUSION

There are two main factors influencing an agent's decision to invest in a new generation cooperative – the value of waiting and the benefit of diversification. In general, when the return on an investment is uncertain there is a positive value to waiting for some uncertainty to be resolved and this will drive his investment threshold upward. This chapter also showed:

- As the level of risk aversion increases, the value of waiting and, consequently, the investment threshold increase.
- As the level of risk increases, the value of waiting and the investment threshold increase.

On the other hand, the desire to achieve a diversified portfolio will tend to drive an agent's investment threshold lower and may even lead to investment in an unprofitable organization. Analysis of an agent's desire to diversify also revealed:

- Changing the corn and ethanol prices has an ambiguous effect on investment. Increasing (decreasing) the corn (ethanol) price lowers the return on shares in the NGC but makes that return relatively less risky. The overall impact on investment depends on which effect is stronger.
- Increasing risk aversion decreases demand for NGC shares when the investment has a negative return. Increasing risk aversion increases demand for NGC shares when the investment has a positive return.

The value of waiting and the benefit of diversification pull demand for NGC shares in opposite directions. Determining which effect is stronger requires numerical solution methods which will be the subject of the next few chapters.

APPENDIX 3.1

Application Of Ito's Lemma

Ito's Lemma says that when a function, *F(x)*, involves a stochastic variable, *x*, which moves according to $dx = a(x,t)dt + b(x,t)dz$, then:

$$dF = \left[\frac{\partial F}{\partial t} + a(x,t)\frac{\partial F}{\partial x} + \frac{1}{2}b^2(x,t)\frac{\partial^2 F}{\partial x^2}\right]dt + b(x,t)\frac{\partial F}{\partial x}dz,$$

where *dz* is the increment of a Weiner process. This means $dz = \varepsilon_t\sqrt{dt}$. If ε_t is standardized so it is normally distributed with mean 0 and standard deviation of 1, then $b(x,t) = \sigma$ and $a(x,t) = 0$. Also, $\mathrm{E}[dz] = 0$ and $Var(dz) = Var(\varepsilon_t) = \sigma^2$.

By Ito's Lemma, the Bellman Equation (3.1) becomes:

$$dW = \left[\frac{\partial W}{\partial t} + a(P,t)\frac{\partial W}{\partial P} + \frac{1}{2}b^2(P,t)\frac{\partial^2 W}{\partial P^2}\right]dt + b(P,t)\frac{\partial W}{\partial P}dz.$$

Observe that $\frac{\partial W}{\partial t} = 0, \quad a(P,t) = 0$, so:

$$dW = \frac{1}{2}\sigma^2 W_{PP}dt + \sigma W_P dz.$$

Consequently,

$$\mathrm{E}[dW] = \frac{1}{2}\sigma^2 W_{PP}dt.$$

CHAPTER 4

PERFECTLY COMPETITIVE MARKET

4.1 OVERVIEW OF THE COMPETITIVE MARKET FOR NGC SHARES

The first type of NGC to be considered is one with a perfectly competitive secondary market for its shares. There are assumed to be many buyers and sellers of shares in each time period so that the market for NGC stock is perfectly liquid and each agent can exercise his optimal trade at the current market price. Agents are assumed to be price-takers and the market-clearing price is that at which aggregate supply is equal to aggregate demand.

The assumptions of perfect competition are not applicable during the period of the NGC's initial stock offering. During the initial offering the supply of shares and the share price are both fixed by the NGC. Consequently, aggregate supply will not generally equal aggregate demand. The NGC forms if demand meets or exceeds supply at the exogenously given share price, and in that case shares are allocated randomly among potential buyers. If demand is less than supply, the NGC does not form.

In the time periods after the NGC's formation, each agent (whether a member or not) submits a demand schedule that identifies the number of shares he is willing to buy or sell at every possible share price. The market clears at the price where aggregate supply is equal to aggregate demand and all trades are completed at the market clearing price.

As a practical matter, for a cooperative's shares to be traded in a perfectly competitive manner there would need to be a large, heterogeneous pool of potential investors and an efficient mechanism for agents to learn and share information. This is likely to be an unrealistic assumption.

It is still worthwhile to study the competitive case, however, as a benchmark in welfare analysis. In a competitive market each agent who buys shares in the NGC is implementing a utility maximizing strategy. Therefore, when a NGC forms, each new member is improving his welfare while non-members suffer no adverse impact on their welfare.[1] Discovering the set of states at which a competitive market NGC should form is then tantamount to identifying the states at which greater efficiency (in the Pareto sense) is possible.

This chapter begins by returning to the general dynamic programming problem described in Chapter 2. The general form of the Bellman equation in the agent problem will first be modified to reflect the specific characteristics of the competitive market. Next, the numerical solutions to the agents' full dynamic programming problem will be discussed. The final section presents the results of competitive market simulations. The formation threshold, share price dynamics, trading volumes, membership distributions and exit thresholds of the NGC in the competitive market will be explained.

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[1] There is evidence that the formation of a NGC also improves the welfare of non-members (Zeuli, 1998).

4.2 APPLICATION OF THE GENERAL DYNAMIC PROGRAMMING PROBLEM TO THE COMPETITIVE MARKET

The agent's problem in the competitive market tracks the recursive problem of Equation 2.3 very closely. Each agent's control variable is the change in his share balance, *X*, and the state variables are the ethanol price, corn price, share price and share balance. The ethanol and corn prices follow the stochastic processes described in Chapter 2. The expected share price is assumed to be a linear function of the ethanol price and corn price, the exact parameters of which will be estimated from the results of the market simulations (see Section 4.4.2). Since the market for NGC shares is assumed to be perfectly liquid and agents are assured of being able to execute their optimal trade, the share balance state equation is a deterministic sum of the previous period's share balance and the optimal policy.

With these modifications, the Bellman equation for an agent in a competitive market becomes:

$$W(EP,CP,SP,SH) = \max_{X}\{\mathrm{E}[U[\Pi(EP',CP' \mid SP,SH,X,\varepsilon)]] + \beta\mathrm{E}[W(EP',CP',SP',SH')]\}$$

subject to:

$$\begin{aligned} &CP' = CP \cdot \varepsilon^{C} \\ &EP' = EP \cdot \varepsilon^{E} \\ &SP' = \alpha_0 + \alpha_1 EP' + \alpha_2 CP' + \varepsilon^{S} \\ &\varepsilon = (\varepsilon^{E}, \varepsilon^{C}, \varepsilon^{S}) \\ &SH' = SH + X \\ &0 \le SH' \le SH_{\max} \end{aligned} \qquad (4.1)$$

Due to the presence of three stochastic state variables, this equation needs to be solved numerically.[2]

4.3 RESULTS OF THE AGENT PROBLEM

4.3.1 The Agent Demand Curve: The Income Effect vs. The Risk-Reduction Effect

Figures 4.1 and 4.2 display demand curves for a representative agent[3]. Figure 4.1 depicts the shift in demand for NGC shares by a representative agent as the ethanol price increases, and Figure 4.2 illustrates the shift in demand for shares as the corn price increases. An increase in the ethanol price increases the demand for shares in the NGC while an increase in the corn price reduces demand.

In Chapter 3 the signs of $\frac{\partial X^*}{\partial EP}$ and $\frac{\partial X^*}{\partial CP}$ were indeterminate because of contrary "income effects" and "risk-reduction effects." A higher ethanol price increases the return on NGC stock (a positive income effect) but also increases the relative variance on that return (a negative risk-reduction effect). The opposite is true for the corn price. Figures 4.1 and 4.2 seem to resolve these issues. In Figure 4.1 an increase in the ethanol price increases demand, so $\frac{\partial X^*}{\partial EP} > 0$. In Figure 4.2 an increase in the corn price reduces demand, so $\frac{\partial X^*}{\partial CP} < 0$. Numerical solutions to the agent problems reveal that the "income effect" dominates the "risk-reduction effect" in both cases.

---

[2] Matlab was used to solve the agent problems. See Appendix B for a description of the solution method and portions of the relevant Matlab code.

[3] The representative agent depicted in Figure 4.1, and used throughout this study, is highly risk averse and has a medium sized farm near the ethanol plant. The shorthand for this agent type is "MNHRA."

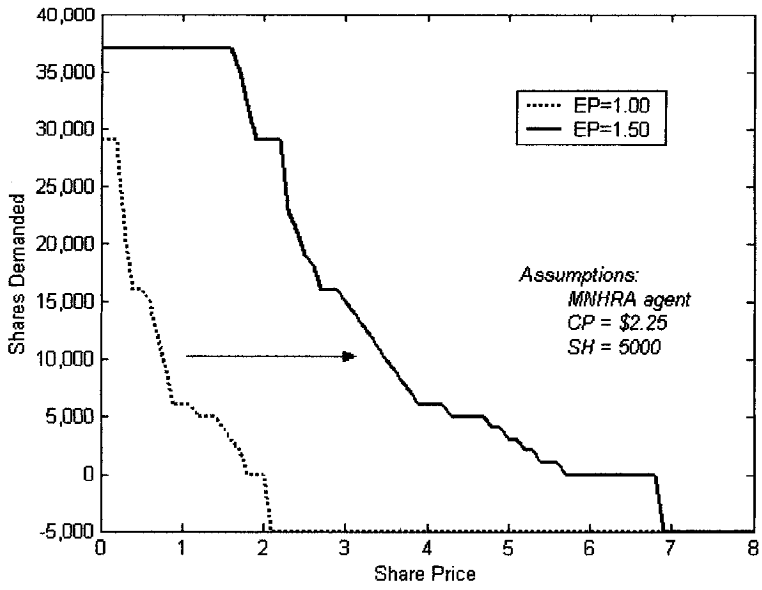

FIGURE 4.1

Demand for NGC Shares as the Ethanol Price Changes

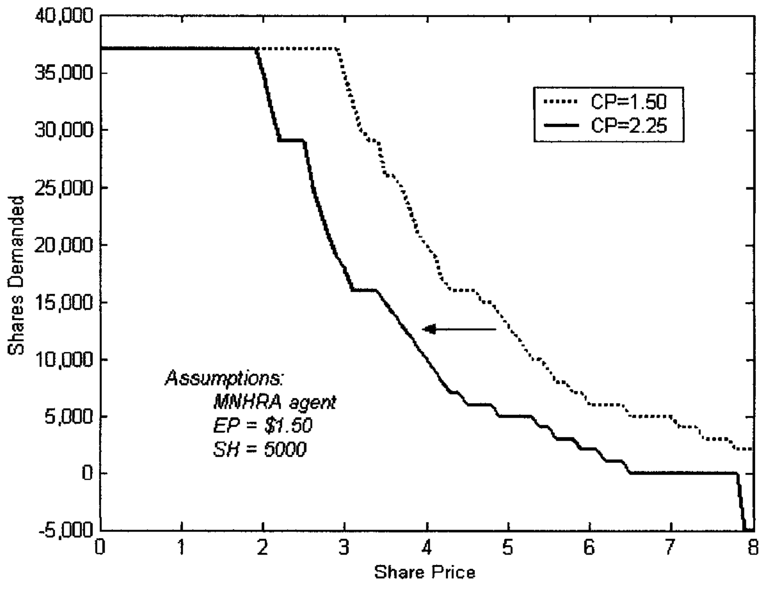

FIGURE 4.2

Demand for NGC Shares as the Corn Price Changes

The demand curves in Figures 4.1 and 4.2 are not vertical, which confirms the analytical prediction of the optimality of an incremental investment strategy. As explained in the previous chapter, the optimality of incremental investment is implied by the decreasing marginal utility of the agent's utility function. Incremental investment is an important point not only because it helps to explain agent behavior but also because the existence of "all or nothing" investment policies would make portfolio adjustments sticky and greatly reduce the liquidity of NGC in the secondary market.

4.3.2 The Agent Investment Threshold: The Value of Waiting vs. The Benefits of Diversification

Figure 4.3 shows the set of states at which the same representative agent will purchase 5,000 shares of NGC stock. States in the northwest corner of the graph result in the highest NGC profit and states in the southeast corner result in the lowest profit. The agent will be willing to increase his holdings in the NGC from zero to (at least) 5,000 shares at all states at or above the investment threshold (the solid line) and will refuse to invest at all states below the line.

The agent's investment threshold is well below the NPV threshold. The real-options approach to investment predicts that with stochastic ethanol and corn prices the value of waiting will result in an investment threshold *above* the NPV line. The benefits of diversification, however, suggest an investment threshold *below* the NPV line. Figure 4.3 makes clear that, in this model, the value of waiting for uncertainty to be resolved is less important than the need to have a diversified portfolio.

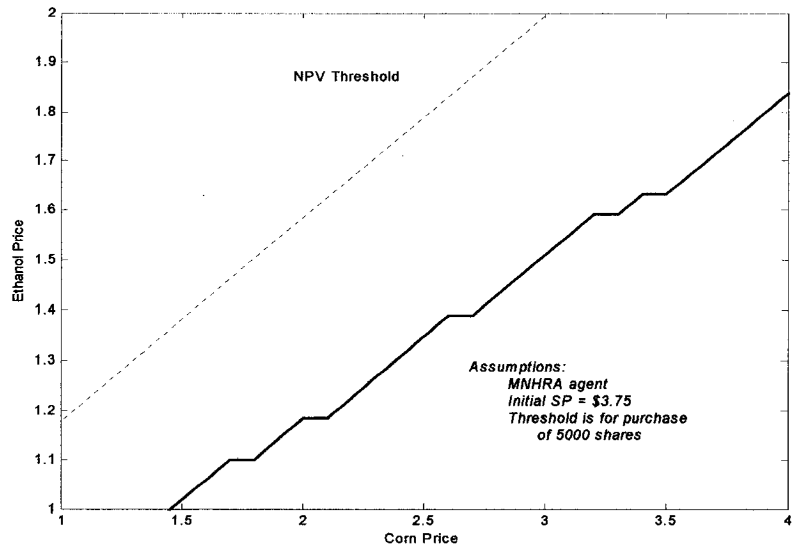

Figure 4.3
Agent Investment Threshold

The value of waiting is much greater when an investor perceives that the investment is irreversible or very expensive to reverse. (Dixit and Pindyck, p.388). If an investor believed he would be unable to sell his interest in the NGC in the future, he would refrain from investing until the NGC was sufficiently profitable to obviate the need to disinvest or, at least, to cover the expected losses of disinvestment. However, a competitive market for NGC stock is perfectly liquid so, except in the extreme case where members abandon the NGC, there is always a buyer if the agent chooses to disinvest. Agents in a perfectly competitive market always face the possibility of a capital loss but this deters initial investment much less than certain irreversibility. The result is that an agent in a perfectly competitive market realizes very little value from waiting.

The value of diversifying, on the other hand, is great. Chapter 3 explained that the benefits of diversification can make it optimal to invest in an unprofitable NGC. Corn and ethanol prices are fairly volatile and this contributes to the need to diversify. (Robison and Barry, p.159). Since the need to diversify outweighs the benefits of waiting, the investment threshold falls well below the NPV line.

4.3.3 The Effect of Risk Aversion

The analysis of Chapter 3 showed that the value of waiting increases as the level of risk aversion increases. An agent with relatively high risk aversion should, therefore, have a *higher* investment threshold. However, when the cooperative's profit is negative, as it is for all states along the investment threshold, the desire to diversify should result in a *lower* investment threshold for agents with higher risk aversion. Figure 4.4 shows that the investment thresholds for agents with high and low levels of risk aversion are very similar, which suggests these effects cancel each other out.

In Figure 4.4 the investment threshold for an agent with high risk aversion has a slightly flatter slope than the investment threshold for the agent with low risk aversion. This means the highly risk averse agent will have relatively greater demand for NGC investment when the corn price is high and relatively less demand when the corn price is low. Using the notation from Chapter 3, the second partial derivative of $\frac{\partial X^*}{\partial CP}$ with respect to the risk aversion factor is:

$$\frac{\partial X^*}{\partial CP \partial \lambda} = \frac{1}{\lambda^2 (\sigma_E^2 + \sigma_C^2)^2} \left[\frac{\partial \sigma_C^2}{\partial CP} \frac{\pi}{(\sigma_E^2 + \sigma_C^2)} - \frac{\partial \pi}{\partial CP} \right] > 0 \qquad (4.2)$$

A positive sign[4] on this expression means that a higher level of risk aversion implies an agent will increase his balance of NGC shares at a faster rate when the corn price is increasing and reduce his share balance at a faster rate when the corn price is decreasing. This reflects the highly risk averse agent's strong desire to diversify in order to avoid the additional risk of a high corn price and explains the flatter threshold.

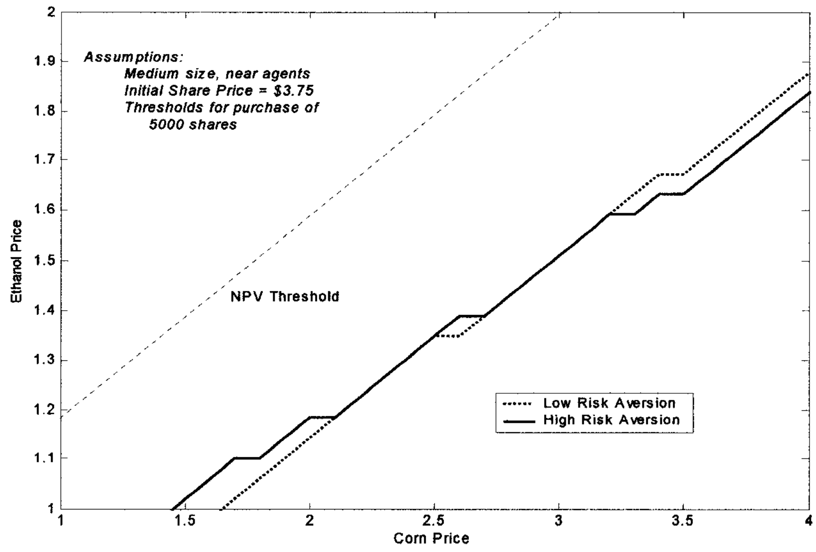

Figure 4.4
Investment Thresholds for Agents with Different Levels of Risk Aversion

4.3.4 The Effect of Changes in Other Agent Characteristics

[4] The term outside of the brackets is positive. In order to sign the term inside the brackets, rearrange Equation 3.16: $\frac{\partial X^*}{\partial CP}=\left(\frac{\partial \sigma_C^2}{\partial CP}\right)\frac{Y\sigma_E^2}{(\sigma_E^2+\sigma_C^2)^2}-\frac{1}{\lambda(\sigma_E^2+\sigma_C^2)}\left[\frac{\partial \sigma_C^2}{\partial CP}\frac{\pi}{(\sigma_E^2+\sigma_C^2)^2}-\frac{\partial \pi}{\partial CP}\right]$. Figure 4.2 shows that $\frac{\partial X^*}{\partial CP}>0$. For this to be true the bracketed term in the expression for $\frac{\partial X^*}{\partial CP}$, which is the same as the bracketed term in Equation 4.2, must be positive. Thus, $\frac{\partial X^*}{\partial CP \partial \lambda} > 0$.

While the impact of changes in risk aversion is complex, the effect of changing an agent's size and distance from the cooperative is fairly straightforward. First of all, a large agent has more corn available to commit to the NGC and requires a greater investment in order to realize equivalent gains from diversification. Therefore, as agent size increases demand for NGC shares also increases.

When an agent is located farther from the cooperative the cost of delivering corn increases and the effective corn price received by the agent is reduced. The per share return from the NGC is, therefore, lower for an agent who is far from the cooperative and he will demand fewer shares than the agent who is near the NGC.

4.4 MARKET SIMULATION RESULTS

4.4.1 Cooperative Formation

The cooperative's formation threshold is the set of ethanol price / corn price combinations at which the aggregate demand for NGC shares at the initial share price is at least as great as the number of shares initially offered for sale by the cooperative. The formation threshold was calculated by determining the demand for shares at the initial offering price for each agent in the simulation population (see §2.5 of Chapter 2). The total demand for shares is simply the sum of the shares demanded by the individual agents.[5]

The NGC formation thresholds for three different initial share prices are shown in Figure 4.5.

[5] See Appendix D for a description of the method for calculating the formation thresholds and the relevant Matlab code.

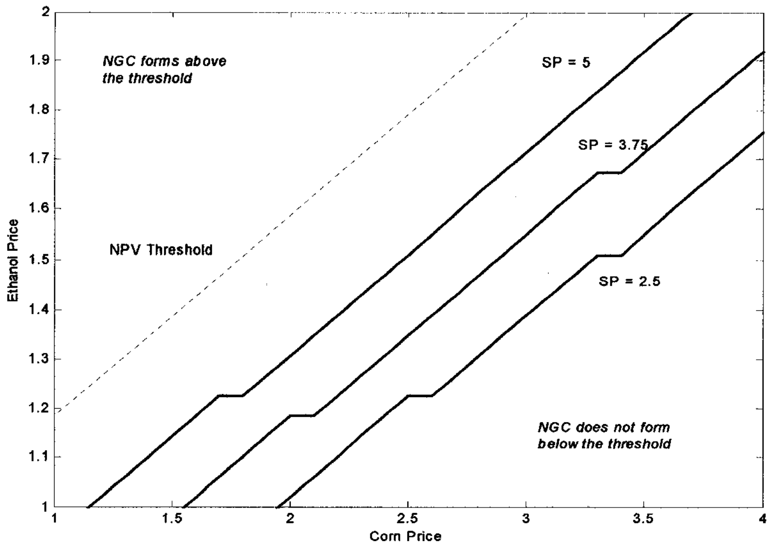

Figure 4.5
Formation Thresholds for NGC with a Competitive Market for its Shares

The most striking result is that the cooperative will form even when the traditional net present value rule suggests investment would be unwise[6]. The area above the formation threshold and below the net present value line represents ethanol price / corn price combinations where the NGC would form but the expected net present value of a cooperative share is less than its share price. The line representing the states that result in a single period profit of zero would be just below the NPV threshold so there are also many states that result in a single period loss for the cooperative but which are favorable for cooperative formation, nonetheless.

The reason the cooperative's investment threshold is below the NPV threshold should be apparent from the earlier discussion of the agent's problem. Figure 4.3

[6] The NPV threshold depicted in Figure 4.5 is for an initial share price of $3.75. The NPV threshold shifts only slightly as the share price changes, so to avoid unnecessary clutter the NPV threshold for SP=$2.50 and SP=$5.00 have been left out.

illustrates that potential investors demand shares in the cooperative as a risk management tool even if immediate losses are expected. Since total demand for cooperative shares is merely an aggregate of the demand of individual investors, it is not surprising that the cooperative could form over a broad range of seemingly unfavorable states.

It is also not surprising that the formation threshold increases as the initial share price increases. Figures 4.1 and 4.2 show that demand for NGC shares decreases with increases in the share price. At the time of the initial stock offering a high share price reduces interest in the NGC and the NGC must then promise a higher return before there will be sufficient interest for the cooperative to form.

4.4.2 Share Price Dynamics

For the model to be complete, agents must have an expectation about the future dynamics of the NGC share price. In this model, agents form rational expectations about the share price dynamics that take the form of a linear function of the corn and ethanol prices:

$$SP = \alpha_0 + \alpha_1 EP + \alpha_2 CP + \varepsilon$$

Initial estimates of the NGC share price parameters were based upon the discounted capitalized value of the NGC shares as well as preliminary simulations using earlier versions of the agent model. These estimated parameters were used to solve each agent's dynamic programming problem and then these results were used to perform small scale market simulations (21 agents and 10 simulations[7]). The results of these simulations were used to estimate new parameters for the share price equation. The individual agent models were updated with the revised share price parameters, new simulations were performed, and this process was continued until the share price model used to solve the agents' problems was not significantly different, at a 95% confidence level, than the share price model estimated from the subsequent market simulation.

Table 4.1 shows the parameters of each set of market simulations. A share price model that included the lagged value of the share price was also estimated. However, the coefficient on the lagged value of the share price was not significant in any iteration. The share price coefficients resulting from the sixth iteration were not significantly different than those resulting from the fifth iteration. As a result, the coefficients and residual variance of the fifth iteration were used to solve the agent problems which form the basis for the final market simulations.

	Intercept Parameter	**Ethanol Price Parameter**	**Corn Price Parameter**	**Variance of Residuals**	**F-Stat**[8] (Comparison with previous iteration)
1st Iteration	-1.76	2.42	-1.36	0.69	--
2nd Iteration	-1.63	3.00	-2.01	0.11	33.41
3rd Iteration	-0.12	2.47	-1.79	0.79	6.15
4th Iteration	1.34	2.23	-1.87	0.47	4.28
5th Iteration	**1.51**	**2.60**	**-2.38**	**0.17**	12.94
6th Iteration	1.62	2.61	-2.48	0.40	0.38

Table 4.1
Estimated Share Price Parameters

[7] A "simulation" is a ten year string of randomly drawn ethanol and corn prices. See Appendix C for the Matlab code.
[8] The critical value is 3.9 at a 99% confidence level and 2.65 at a 95% confidence level.

Computing limitations prevented the use of larger simulations to conduct the share price iteration process, but more extensive simulations (42 agents and 50 simulations) were performed after the "rational" share price parameters were determined. The NGC share price was estimated again using data from the larger set of simulations and it was discovered that the share price coefficients were impacted slightly. As a result, agents expectations are "nearly rational." This discrepancy seems to have little impact on agents' demand for shares and has no impact on the relative demand of different agent types.

4.4.3 Trading Volume

The volume of NGC shares that are traded decreases significantly over time. Figure 4.6 shows the average trading volume, over 50 simulations, in each year of the cooperative's existence as a percentage of the total number of shares available. In the year immediately after the NGC's formation the average trading volume is 11.7% of outstanding shares. Volume declines steadily for the next four years, and by the seventh year the trading volume settles to about 4% of outstanding shares.

The high volume of trading immediately after the NGC's formation is due to excess demand for shares in the year of the formation. When a NGC forms the demand for shares exceeds the number of shares available unless the ethanol and corn prices both fall exactly on the NGC's investment threshold. In this model, and in practice, the limited number of NGC shares are unlikely to be allocated to the agents who place the greatest value on them.[9] The higher trading volume in the time periods immediately after formation reflects a reshuffling of shares from agents that place a lower marginal value on the traded shares to agents who place a higher marginal value on the shares.

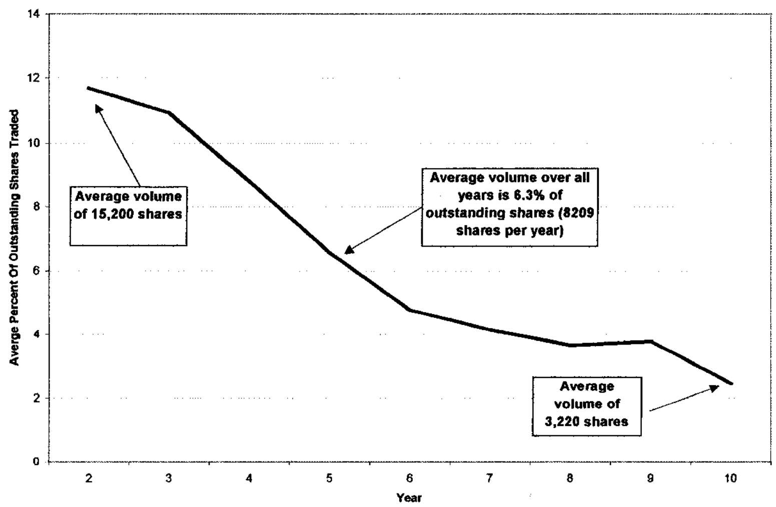

Figure 4.6
Average Percentage Of Outstanding Shares Traded, By Year

After approximately four time periods, the volume of trading levels out to between three and five percent of outstanding shares. By this time, NGC shares have found their way into the portfolios of agents who value them the most. Trading at this stage of the cooperative's existence tends to result from agents' differing responses to changes in the ethanol and corn prices.

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[9] In the model, shares are allocated randomly. In practice, shares are likely to be allocated on a first come basis. This system may tend to allocate shares to the producers most eager to purchase them, but by no means guarantees it.

A closer look at the dynamics of the share price supports these conclusions. Table 4.2 shows that estimates of the share price in the period from year 2 to year 5 are significantly different from estimates for the period from year 6 to year 10. The intercept term in the early years of the NGC's existence is much higher than the intercept in the later years. As a result, the estimated share price at identical states is, on average, $0.75 higher in years 2 through 5 than it is in years 6 through 10. This is the result of agents who place a high value on NGC shares, but were not initially allocated their optimal amount of shares, attempting to purchase additional stock in early time periods and bidding up the share price.

	Intercept	**Ethanol Price**	**Corn Price**
Coefficients for Yrs. 2 through 5	3.3566	1.7712	-1.7134
Coefficients for Yrs. 6 through 10	2.1423	2.0701	-1.9442
F-Statistic		12.173	

Table 4.2
Share Price Coefficients
Early and Late in the NGC Existence

The coefficients on the ethanol and corn prices are larger for years 6 through 10 than they are in the previous time period. This implies the NGC share price is more responsive to changes in the ethanol and corn price in later years than it is in early years. This observation is consistent with the theory that by year 6 most of the NGC share have been allocated to agents who value them the most, and that trading in the subsequent time periods is the result of agents adjusting to corn and ethanol price fluctuations.

4.4.4 Membership Distribution

By the end of each ten year simulation the volume of trading settles and the distribution of agent types within the NGC membership tends toward a common membership profile. Figures 4.7, 4.8 and 4.9 show the average percentage of NGC members who are of a particular type at the end of the simulations. It also shows the percentage of NGC shares owed by each type of agent. In this figure, both of these measures of membership distribution are juxtaposed against the percentage of each agent type in the overall population.

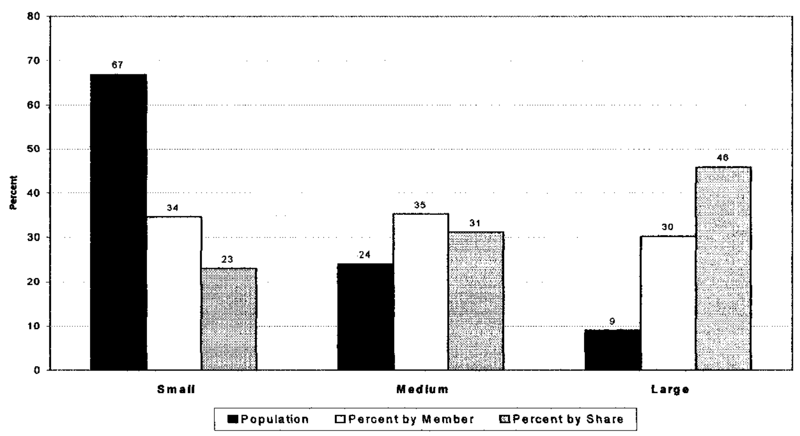

Figure 4.7
Agent Distribution by Size

Figure 4.7 suggests that a NGC with a competitive market for its shares will tend to have a disproportionately high number of large sized agents in its membership. The overall percentage of members in the NGC who are large is very similar to the percentage who are small or medium sized, but large agents make up only a fraction of the population. If the membership distribution is measured by the number of shares rather than the number of members, large agents own nearly half of the NGC stock despite being only nine percent of the population. This is not surprising since a large sized agent has more corn to commit to the NGC and needs to own more NGC shares than its smaller counterparts in order to enjoy the equivalent benefits of diversification.

Figure 4.8 shows the distribution of members by their level of risk aversion. A slight majority of NGC members tend to have low levels of risk aversion, which is nearly in line with the equal division of high and low levels of risk aversion in the overall population. Measured in terms of shares, a greater proportion of shares are owned by agents with low risk aversion. These results are consistent with the earlier conclusion that agents with lower levels of risk aversion will have a slightly greater demand for NGC shares over most, but not all, ethanol / corn price pairs.

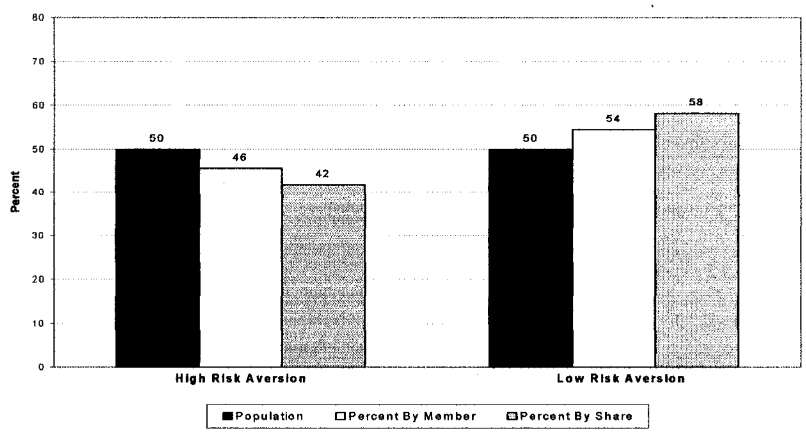

Figure 4.8
Agent Distribution by Risk Aversion

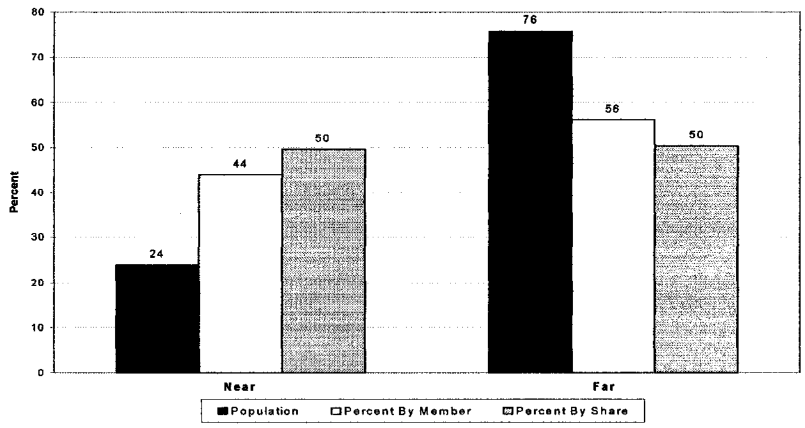

Figure 4.9
Agent Distribution by Distance

Finally, Figure 4.9 shows that the NGC membership strongly favors agents who are near the cooperative. Agents who are near the cooperative have a cost advantage over those who are far from the cooperative, and consequently have a greater demand for the NGC shares. Despite being less than a quarter of the population, agents who are near the cooperative tend to own half of the NGC shares.

4.4.5 The NGC's Exit Thresholds

4.4.5(a) Overview

An important question surrounding new generation cooperatives is their susceptibility to takeover by investor-owned firms. The first step in answering that question is to determine, at every ethanol price / corn price combination, the share price at which a sufficient number of the members of the cooperative would vote to sell their shares to an IOF.

Non-members have no vote on the matter of demutualization, so it is only necessary to consider the optimal policies of NGC members. Member types and their respective share balances are assumed to have the "typical" distribution described in Appendix 4.1. It is also assumed that the IOF would be unwilling to purchase a fraction of the NGC shares, so members' optimal policies are limited to either selling all of their shares or selling none of their shares. If the share price offered by an IOF is denoted $\overline{SP}$, each member of the NGC optimizes by solving[10]:

$$W(EP,CP,\overline{SP},SH) = \max_{X}\left\{E\left[U[\Pi(EP',CP' \mid \overline{SP},SH,X,\varepsilon)]\right] + \beta E\left[W(EP',CP',SP',SH')\right]\right\}$$

subject to:

$$\begin{aligned} CP' &= CP \cdot \varepsilon^{C} \\ EP' &= EP \cdot \varepsilon^{E} \\ SP' &= \alpha_0 + \alpha_1 EP' + \alpha_2 CP' + \varepsilon^{S'} \\ SH' &= SH + X \\ &\quad where\ X = -SH\ or\ 0 \end{aligned} \tag{4.3}$$

Figures 4.1 and 4.2 show that as the share price increases, the members' optimal policies approach $X^{i} = -SH^{i}$. In other words, every member has a share price at which he can be enticed to sell all of his shares. At some point, the share price will reach the level where enough members want to sell their shares to permit a takeover to occur. The question of what are "enough" members depends on the voting rules employed by the NGC. This section looks at voting by one-member / one-vote as well as voting by one-share / one-vote. Each voting rights mechanism will then be subjected to the requirements of a simple majority and a two-thirds majority.

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[10] The inclusion of the continuation value in Equation 4.3 assumes that a market for NGC shares will remain regardless of the agents' choice of X. This is true if $X \neq 0$ for a sufficient number of members. This assumption is true in the event of a takeover only if there is another NGC the agent could join. Since this is probably the case for most producers (although the cost structure of another NGC is likely to be different) I will assume the takeover decision is, in a loose sense, reversible.

The minimum share price at which the NGC would agree to a takeover at a given ethanol price / corn price pair is found by solving Equation 4.3 for every member over the range of possible offering prices and then adding up the number of members or number of shares (depending on the voting rule) who wish to sell at each share price. A takeover becomes possible at the lowest share price at which a majority of votes are to sell.

4.4.5(b) The effect of changes in the offering price

A NGC's "exit threshold" is the set of ethanol price / corn price pairs that separate the region where the cooperative would vote to sell its shares from the region where it would not. Figure 4.10 shows the NGC's exit thresholds for five different share prices, assuming that a takeover would require a simple majority of members to vote in favor of it. In the area above each threshold the NGC would not sell but in the area below the threshold a takeover could occur at the designated offering price.

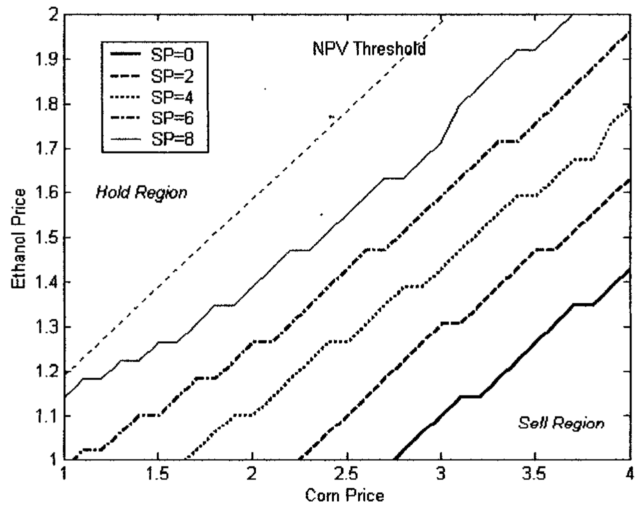

Figure 4.10
Exit Thresholds for Various Offer Prices when Voting Requires a Simple Majority of Members

When the offering price is low, the members will vote to sell only when the NGC is very unprofitable. As the offering price rises the members of the NGC will vote in favor of a sale at increasingly favorable states. However, in the competitive market situation the NGC members would not agree to the takeover of a profitable NGC even when the offering price is at $8.00 per share, the maximum allowed by the model.

4.4.5(c) Abandonment

The exit threshold analysis is not only helpful in determining when a takeover might occur but it can also be interpreted to identify the region when members would abandon the NGC. A NGC will be "abandoned" when a sufficient number of members would vote to have the NGC cease doing business and liquidate its assets. Assuming revenue from selling the NGC's assets is less than the cooperative's debt, abandonment is equivalent to selling all of a member's shares for zero dollars. The NGC's abandonment region is then the area below the exit threshold for $SP = 0$.

4.4.5(d) The effect of changes in voting rules

A cooperative's voting rules will also affect the exit threshold. A NGC that requires two-thirds of its members to agree to approve a sale of its assets will be less likely to be taken over than a NGC that requires a simple majority because an additional 17% of the membership must be convinced to sell their shares at the offered price. In addition, Section 4.4.4 showed that the percent of members of a certain type might differ from the percent of shares owned by that type. Therefore, the decision to sell the NGC assets will also hinge on whether the NGC employs a one member / one vote system or a one share / one vote system.

Alternative voting rules are important to Minnesota's new generation ethanol cooperatives because NGC's now have the ability to choose a variety of voting mechanisms. Prior to August 1, 2003, Minnesota law required cooperatives to use the one member / one vote rule. (Minn. Stat. 308A). It also required two-thirds of members to vote in favor of the sale of the NGC's assets. A new statute effective August 1, 2003 allows a cooperative to choose either a one member / one vote or a one share / one vote rule (Minn. Stat. 308B.551, subd.1). The new law also allows for the cooperative to sell all of its assets upon the vote of a simple majority, although the NGC may employ a super-majority rule if it chooses. (Minn. Stat. 308B.571, subd.2.)

Figure 4.11 shows the different exit thresholds for a NGC that uses a simple majority rule and one that uses a two-thirds majority rule. Figure 4.12 shows exit thresholds for member voting and share voting rules. Both figures assume an offering price of $3.00 per share.

The choice of majority size has surprisingly little impact on the NGC's exit threshold. This is largely due to the lack of significant heterogeneity in the membership. Homogeneity across agents means that the marginal voter in a simple majority acts very much like the marginal voter in a super-majority. Consequently, the exit thresholds are very similar.

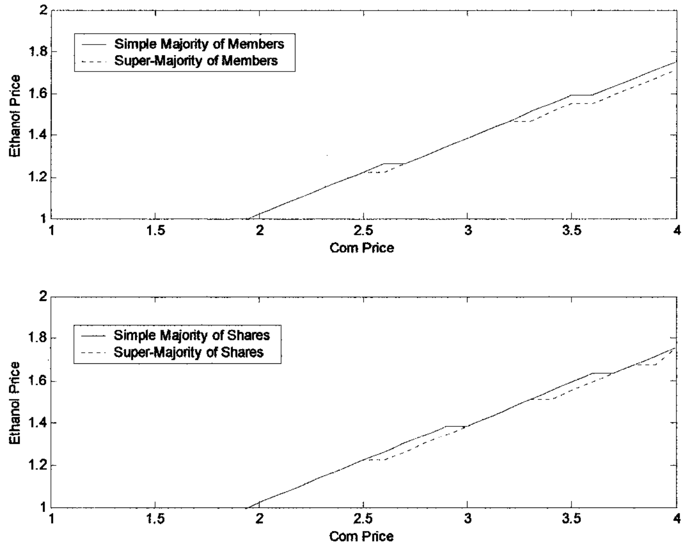

Figure 4.11
Effect on the Exit Threshold from Changing the Majority Requirement

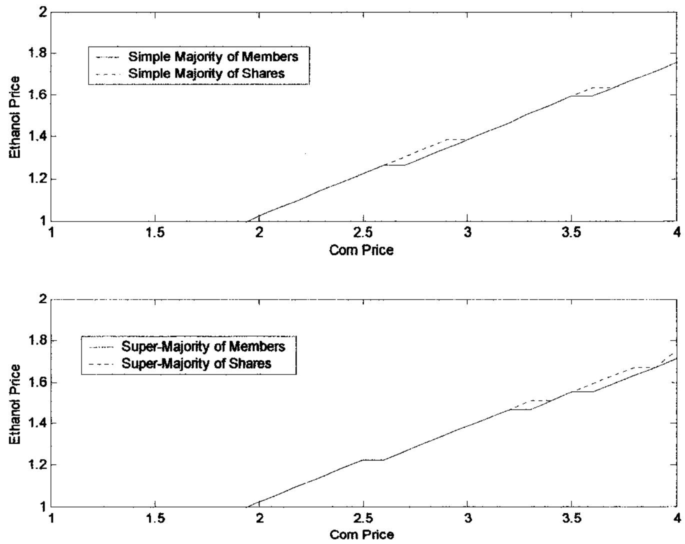

Figure 4.12
Effect on the Exit Threshold Due to a Change from Member Voting to Share Voting

Share voting results in an upward shift in the exit threshold, although the overall impact of this change is also small. Large members tend to hold more shares and so have a greater influence when a NGC adopts share voting. Large members typically act more risk neutrally, and as a result are quicker to completely disinvest from the NGC. Therefore, when share voting is used the large members' influence nudges the exit threshold above the member voting threshold.

4.5 CONCLUSION

This chapter examined the behavior of individual agents and the characteristics of the NGC when the cooperative's shares are traded in a competitive market.

Numerical solutions to the agent models revealed:

- Demand for NGC shares increases with an increase in the ethanol price and a reduction in the corn price. This means that the "income effect" from a price changes outweighs the "risk-reduction effect."
- Agents' investment thresholds are well below the threshold predicted by the net present value rule. This means that the benefits of diversification outweigh the value of waiting for uncertainty to be resolved.
- Changing the level of risk aversion has little effect on the investment thresholds, although a higher level of risk aversion implies a more aggressive response to changes in the corn price.
- Larger farms and proximity to the cooperative are factors that increase demand for NGC shares and lower agent investment thresholds.

The results of the agent problems were linked and market simulations were performed to evaluate the nature of the market for NGC shares. The simulations suggest:

- NGC's are likely to form under conditions less favorable than the net present value rule predicts they would. In fact, the value of diversification makes NGC formation rational even when the cooperative is unprofitable.

- The volume of trading in NGC shares is likely to be high in the time periods immediately after formation but subsides once shares have reached the hands of the agents who value them the most. The drop in trading volume coincides with a drop in the share price.

- The NGC membership is dominated by large agents who are located close to the cooperative.

- There are many circumstances where the members of the NGC should be willing to sell the cooperative's assets. The exact states at which the members would vote to sell the NGC depend on the offering price and the NGC's voting rules.

APPENDIX 4.1

Distribution of Agent Types Used In Exit Threshold Analysis

In order to do the exit threshold analysis it was necessary to designate a NGC membership that was representative of the memberships observed in the market simulations. The membership used in the competitive market exit analysis is as follows:

Number and Share Balance Of Each Agent Type		
Type	Number of this type	Share Balance per member
SNHRA	1	5000
SNSRA	1	5000
SFHRA	1	8000
SFSRA	1	12000
MNHRA	1	7000
MNSRA	1	9000
MFHRA	1	14000
MFSRA	1	10000
LNHRA	1	16000
LNSRA	1	23000
LFHRA	1	5000
LFSRA	1	16000

The chart below shows how the producer characteristics of the exit threshold membership compare with the characteristics of the membership at the end of the market simulations.

Percentages of Agent Types In Simulation and In Exit Analysis				
Type	Percent from simulation (by shares)	Percent used in exit threshold analysis	Percent from simulation (by member)	Percent used in exit threshold analysis
Small	23.03	23.08	34.59	33.33
Medium	31.12	30.77	35.25	33.33
Large	45.85	46.15	30.16	33.33
Near	49.63	50.00	43.90	50.00
Far	50.37	50.00	56.10	50.00
High R.A.	41.80	42.31	45.54	50.00
Low R.A.	58.20	57.69	54.46	50.00

CHAPTER 5

AUCTION MARKETS

5.1 OVERVIEW OF DISCRIMINATORY AND COMPETITIVE AUCTIONS

Several ethanol cooperatives in Minnesota, including Exol, facilitate trading of their shares by conducting periodic multi-unit, sealed-bid double auctions. Multi-unit auctions are distinguished by the presence of more than one unit of a homogeneous good available to be traded. In a sealed-bid double auction there are many buyers and many sellers, each of whom simultaneously submit a price at which they are willing to trade (McAfee and McMillan, 1987, p.725-26). In this chapter, two types of multi-unit, sealed-bid double auction mechanisms will be examined: discriminatory auctions and competitive auctions. The main difference between these two auction mechanisms is that a successful bidder in a discriminatory auction pays his bid price and a successful bidder in the competitive auction pays the "market-clearing" price (Nautz, 1995, p.302).

5.1.1 General Market Structure

In a sealed-bid double auction, each agent, *i*, optimizes the discounted sum of expected utility of net cash flow by submitting an optimal quantity / price pair (Q_i , P_i) at the beginning of each time period. This differs from a competitive market in that there are now two choice variables and the share price is no longer a state variable. The price submitted by each agent must be non-negative and the quantity may be positive (a buyer), negative (a seller), or zero. A buyer's price is a "bid price" and a seller's price is a "reserve price." The quantity / price pair is not revealed to other market participants.

The auction market clears through an auctioneer who ranks the price / quantity bids and prepares schedules of aggregate supply and demand (McAfee, p.725). The price at which supply and demand are equal is called the "stop-out price" (Nautz, p.302). A buyer who submits a bid price higher than or equal to the stop-out price will be successful and a seller who submits a reservation price equal to or lower than the stop-out price will be successful.

The only difference between a discriminatory auction and a competitive auction is the price at which trades are executed. In a competitive market all trades are executed at that period's stop-out price. In a discriminatory auction, however, a successful buyer pays his bid price and the price received by a successful seller depends on which buyer purchases her shares. In this model, the matching of buyers and sellers is determined by a "randomized rationing rule," which says that each of the successful sellers has an equal probability of being matched with any one of the successful buyers. This method greatly simplifies the model[1] and, since the ranges of successful bid and reservation prices tend to be relatively narrow, the choice of matching rule does not significantly alter the results.

[1] Consider an auction where the lowest reserve price is matched with the highest bid. In this case, the sellers have an incentive to lower their reserves in order to increase the expected price they will receive. This greatly complicates the model and may be impossible to solve in this setting. (Casson, 1993)

5.1.2 The Probability of Success

These auction mechanisms introduce an important strategic element that is not found in the competitive model. This results from the fact that over most states there is some probability that an agent's optimal policy will not be successfully executed. For example, if the states are such that the cooperative is very profitable then many agents will likely be trying to buy and the probability of being successful with a relatively low bid price will be close to zero. A seller, on the other hand, would have a high probability of being able to sell in that environment with even a high reserve price. Consequently, the optimal price submitted by agents reflect, in part, an effort to improve their odds of success.

In order to estimate the probability that a bid will be successful and to obtain a solution to this problem, some simplifying assumptions must be imposed.

> *Assumption 1:* Buyers believe that sellers' reservation prices are the result of a random process of nature and are not arrived at strategically.
>
> *Assumption 2:* Sellers believe that buyers' bid prices are the result of a random process of nature and are not arrived at strategically.
>
> *Assumption 3:* All agents have the same beliefs about the distribution of bids and asks.

These assumptions are similar to those imposed by Cason (1993) and Friedman (1991).

With these assumptions, the probability of executing one's optimal policy can be represented by the function:

$$\Phi(EP,CP,P)=\begin{Bmatrix}\Phi_{+}=\Pr(P\geq SOP)\ if\ Q>0\\ \Phi_{-}=\Pr(P\leq SOP)\ if\ Q<0\\ =1\qquad\qquad if\ Q=0\end{Bmatrix}$$

where P is the bid or reserve price, Q is the quantity of shares bid upon, and SOP is the stop-out price. This says that the probability of being successful in the auction is not a function of the quantity of shares available or the quantity bid but is solely a function of the ethanol price, corn price and the bid or reservation price. In practice, sellers of NGC shares would first identify the quantity they wished to sell and then buyers would bid on the available shares. In this model these two steps have been collapsed into a simultaneous exchange so that buyers do not know the quantity available for sale. However, since the ethanol and corn prices are indicative of the quantity of shares likely to be available for sale, the effect of assuming buyers' lack of knowledge of the quantity available is mitigated by the structure of the probability function.

The probability function, Φ, has been constructed using an iterative method similar to that used to estimate the share price dynamics in the competitive model (see Appendix 5.1). The method involves first estimating, from simulation data, an equation for the highest bid price and lowest reserve price in each time period as functions of the corn and ethanol prices. Normal distributions were then constructed around each expectation (Figure 5.1). By assuming that the probability of a certain bid price being successful is equal to the probability that it is higher than the lowest reserve price, Φ_{+} becomes simply the cumulative of the reserve price density function.[2] Conversely, Φ_- is 1 minus the cumulative of the bid price density function. An example of Φ, as well as the bid and reserve price density functions, for a corn price of $2.40/bu. and an ethanol price of $1.50/gal. is shown in Figures 5.1 and 5.2.

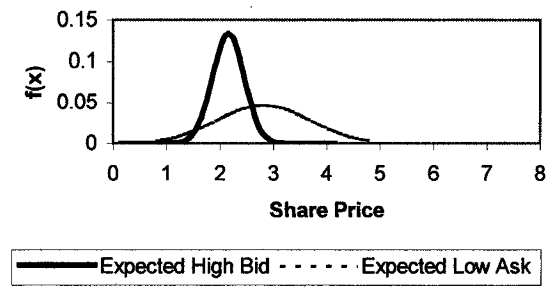

Figure 5.1
Bid and Ask Density Functions

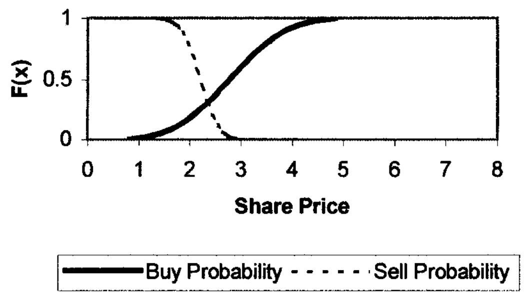

Figure 5.2
Buy and Sell Probability Functions(Φ)

5.1.3 Expected Share Prices

The auction models contain an additional strategic element. The buyer and seller in the competitive auction and the seller in the discriminatory auction are likely to trade at prices different than their bid or reserve prices. Only the buyer in the discriminatory auction actually trades at his bid price. The other agents must form an expected share price that is based upon their bid or reserve prices. This decision is strategic because a high bid price results in a higher expected share price while bidding too low reduces the probability of success. The opposite is true for a seller.

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[2] Bidding higher than the lowest reserve does not technically guarantee success since there could be many bids higher than the lowest reserve. More accurately, bidders would form expectations about the highest successful reserve price and bid strategically based on those expectations. This would be very complicated to model and would not add much given the low volume of trading in the NGC share markets

She maximizes her expected share price with a high reserve price, but a high reserve price also reduces her odds of success.

In a discriminatory auction market the share price a seller actually receives depends on the buyer with whom she is matched. She forms an expectation of her actual share price from the distribution of the expected high bid price (see Figure 5.1). This distribution is truncated from below by the seller's reserve price (since she cannot receive any price below her reserve price) and an expected share price is calculated from the truncated distribution. Her expected share price is then an increasing function of her reserve price.

In the competitive auction model, every agent forms an expectation of his or her share price based on the distribution of the expected stop-out price. The stop-out price is a random variable that is normally distributed around a mean which is a function of the corn and ethanol prices. The stop-out price distribution is truncated from below for a seller and truncated from above for a buyer. Consequently, even though all agents have the same expected stop-out price, the seller will have an expected share price that is higher than the expected stop-out price and the buyer will have an expected share price that is lower than the expected stop-out price. Both expectations are increasing functions of the agent's optimal price.

5.2 APPLICATION OF THE GENERAL DYNAMIC PROGRAMMING PROBLEM TO THE AUCTION MARKETS

The Bellman equation for the general auction problem is:

$$W(EP,CP,SH) = \max_{Q,P}\{E[U[\Pi(EP',CP',SP,X \mid P,Q,SH,\varepsilon)]] + \beta E[W(EP',CP',SH')]\}$$

subject to:

$$\begin{aligned}
&CP' = CP \cdot \varepsilon^{C} \\
&EP' = EP \cdot \varepsilon^{E} \\
&SP = g(EP,CP,P,\varepsilon) \\
&\varepsilon = (\varepsilon^{C},\varepsilon^{E},\varepsilon^{S}) \\
&SH' = SH + X \\
&X = \begin{cases} Q \textit{ with probability } \Phi(EP,CP,P,\varepsilon) \\ 0 \textit{ with probability } (1-\Phi) \end{cases} \\
&0 \leq SH' \leq SH_{\max}
\end{aligned} \tag{5.1}$$

The only difference between the discriminatory and competitive auction models is in the calculation of the share price. In the discriminatory auction $SP = P$ for buyers and $SP(EP,CP,P,\varepsilon) \geq P$ for sellers. In the competitive auction market, $SP(EP,CP,P,\varepsilon) = SOP$ for all market participants.

The auction problem is complicated in the years prior to the cooperative's formation because the share price is set by the NGC rather than chosen by the agent. In that situation, the agents choose only an optimal quantity to purchase at the exogenously given share price and the expected probability of success is assumed to be equal to one. The Bellman equation is:

$$W(EP, CP, SH) = \max_{X} \left\{ \mathrm{E}\left[U[\Pi(EP', CP' \mid SP = \overline{SP}, X, \varepsilon)] \right] + \beta \mathrm{E}\left[W(EP', CP', SH') \right] \right\}$$

subject to:

$$\begin{aligned} & CP' = CP \cdot \varepsilon^{C} \\ & EP' = EP \cdot \varepsilon^{E} \\ & \overline{SP} \textit{ given} \\ & \varepsilon = (\varepsilon^{C}, \varepsilon^{E}) \\ & SH' = X \\ & 0 \leq SH' \leq SH_{\max} \end{aligned} \tag{5.2}$$

The first term is the net cash flow in the current year and it is determined by the number of shares the agent decides to purchase, the expected state, and the share price that the cooperative has set, $\overline{SP}$. The continuation value is the discounted value function determined by solving the Bellman equation in Equation 5.1. In other words, in periods prior to the NGC's formation the agent splices together a dynamic programming problem of two control variables with a maximization problem of a single control variable.

5.3 RESULTS OF THE AGENT PROBLEM

5.3.1 Optimal Prices and Quantities

Figure 5.3 shows how optimal prices and quantities for a representative agent vary with the ethanol price in both the discriminatory and competitive auction markets[3]. In both markets, the agent will sell shares when the ethanol price is low (below approximately $1.20) and the NGC's profit is small. As the price of ethanol rises and the NGC becomes more profitable, the agent will become a buyer. In both

[3] The figure assumes an average corn price of $2.25/bu., a share balance of 5000 shares, the same representative agent characteristics as the previous chapter (medium sized, near the plant, and highly risk averse).

cases, increases in the ethanol price cause the bid price to increase and the bid quantity to decrease. However, the agent in the competitive auction market consistently bids a higher price and quantity than if he were in a discriminatory auction market. The next two sections will discuss the reasons for this.

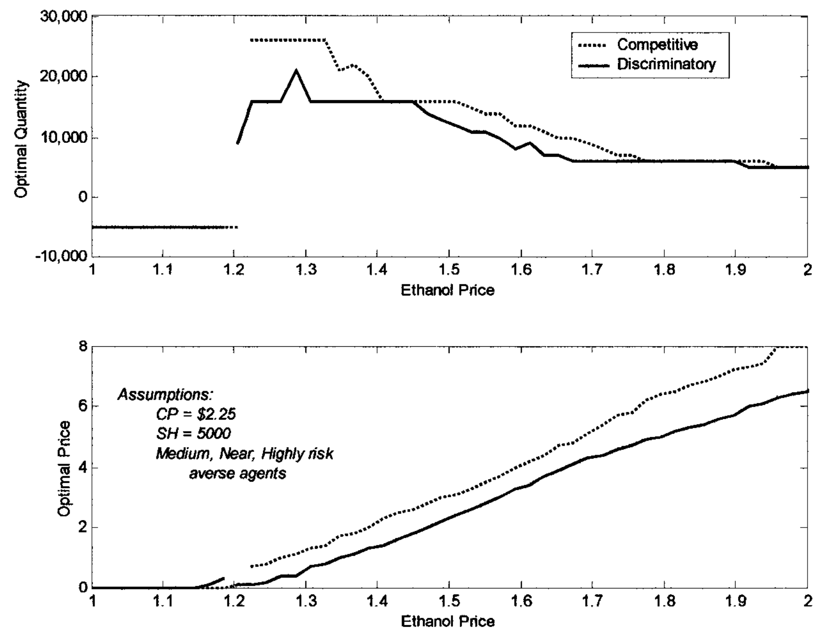

Figure 5.3
Optimal Quantity / Price Pairs as the Ethanol Price Changes

5.3.1(a) Optimal Prices: The Effect of Market Thinness

The agent in a competitive auction market always has a higher optimal bid price and a lower optimal reserve price than the agent in a discriminatory auction market. A useful way to understand the reason for that disparity is to compare the agents' optimal bid prices with their "true valuation" of the shares bid upon. The agent's true valuation is the maximum price he would be willing to pay for the quantity of shares bid upon if the share price and probability of executing the trade were both certain.[4] Figure 5.4 compares the optimal bid in the discriminatory auction market with the true value and Figure 5.5 compares the optimal bid in the competitive auction market with the true value.

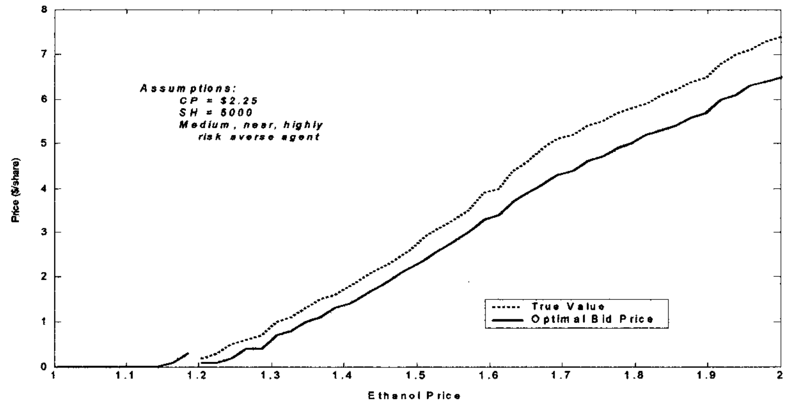

Figure 5.4
Bid Shading in the Discriminatory Auction Market

Figure 5.4 shows that a buyer's optimal bid is always below his true value of the shares. This is consistent with previous studies that argue discriminatory auctions create incentives for agents to "shade" their bids. (Nautz (1995), and Nautz and Wolfstetter (1997)). Intuitively, bid shading occurs because a buyer knows he must pay his bid if he is successful and so attempts to bid as low as possible without slipping below the stop-out price. Bidding significantly above the expected stop-out price, while it may be closer to his true valuation of the shares, increases the cost of acquiring shares without significantly increasing the probability of success. Therefore, the optimal bid price tends to balance a reasonable probability of success against a favorable share price.

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[4] In the case of a seller, the true valuation is the minimum she would be willing to accept. For clarity, the next few sections will discuss the buying side of the market, but the analysis is generally applicable to the selling side also.

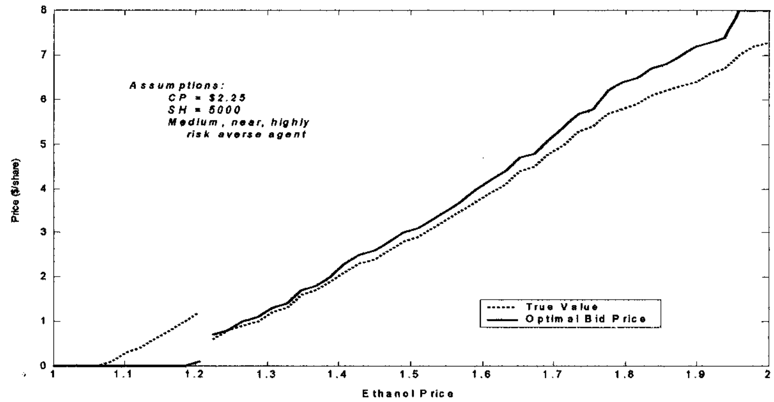

Figure 5.5
Aggressive Bidding in the Competitive Auction Market

A buyer in a competitive auction market is guaranteed to pay a price that is less than or equal to his bid price and, therefore, has an incentive to submit a much higher bid. In fact, Figure 5.5 shows that the optimal policy for an agent in the competitive auction market is to submit a bid *above* his true valuation. This is because an increase in the share price will typically have a large positive effect on the probability of success but only a modest impact on the expected share price, which depends more on the ethanol and corn prices than the agent's bid.

It is a bit misleading to say that an agent in the competitive auction will bid above his true valuation because he does not actually believe he will *pay* a price above his true valuation. Figure 5.6 plots the optimal bid prices in the competitive auction (C.A.) market and the discriminatory auction (D.A.) market against the expected share price, given the optimal bid, in the competitive auction market. This shows the agent in the competitive auction market will submit a bid price that results in an expected share price approximately equal to the price that he would bid in the discriminatory auction market. In other words, the optimal policies in both markets result in about the same expected share price. So while the agent in the competitive market appears to be bidding above his true valuation, his expected share price is actually well below his true valuation.[5]

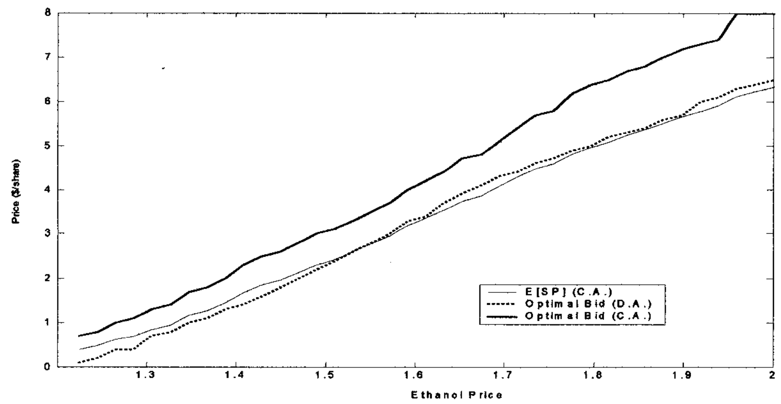

Figure 5.6
Optimal Bids and the Competitive Auction Market Expected Share Price

5.3.1(b) Optimal Quantities: The Value of Waiting

Agents in both markets choose their bid prices in order to achieve an expected share price that is optimal given the incentives to bid shade. But how do agents pick their optimal quantities? Figure 5.3 showed that the agent in a competitive auction market consistently submits a higher quantity than he would in the discriminatory auction market, even though his expected share price is approximately the same. This phenomena can be explained by the fact that the discriminatory auction market is thinner and agents in that market consequently place a higher value on the ability to delay investment.

[5] This result differs from Nautz (1995), who found the optimal policy in a competitive auction was to bid one's true valuation. However, in that case the bidding mechanism was to submit a schedule of quantities for each possible stop-out price. The agent's incentives are different when, as in this case, the agent submits a single bid price that affects the expected share price.

One way to approach this issue is to first compare the optimal bid quantity in the auction market with the quantity purchased in a competitive market by the same agent if the market price were the bid price. Figure 5.7 plots the difference between an agent's optimal bid quantity and the amount he would demand in a perfectly competitive market at the optimal bid price. This graph shows that agents in both the discriminatory and competitive auction markets bid a lower quantity than they would purchase in a perfectly competitive market. The difference is much more pronounced in the discriminatory auction market.

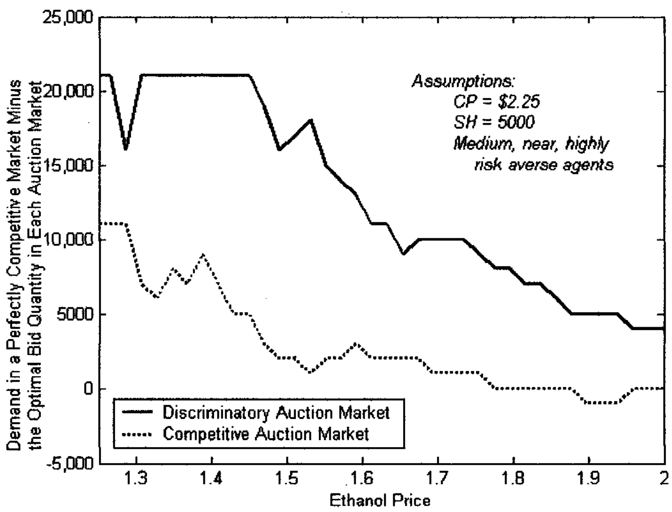

Figure 5.7
Differences Between Demand in the Perfectly Competitive Market and Optimal Bid Quantities in the Competitive and Discriminatory Auction Markets

In Chapter 3 it was shown that the value of waiting reduces demand for NGC shares and the benefits of diversification increase demand for shares. Agents' lower demand for NGC shares in the auction markets, therefore, must be explained by either a higher value to waiting or a lesser benefit from diversification. The value of diversification is driven by the cooperative's profit and the variances of the ethanol and corn prices. These variables depend solely on the corn and ethanol prices and so are independent of the market trading mechanism. Since the benefits of diversification are the same in the competitive market and auction markets, any difference in demand must come from disparities in the value of waiting.

When an investment is completely or partially irreversible the value of waiting to invest is increased. (Dixit and Pindyck, p.388). Intuitively, if there is a possibility that an investor will be unable to resell NGC shares, he has a strong incentive to delay the purchase until the NGC is so profitable that he will either have no need to resell them or will be guaranteed a sufficient return to cover any losses that might occur if resale is difficult. In the auction markets, the presence of the Φ function creates the probability that an attempt to resell shares will be unsuccessful and, consequently, introduces an irreversibility. This irreversibility is also present on the selling side of the market.

The irreversibility is greater in the discriminatory auction market. A comparison of the probability of selling in the competitive auction market with the probability of selling the discriminatory auction market at comparable corn, ethanol and reserve prices reveals:

$$\Phi_{-}^{C}(P,EP,CP) > \Phi_{-}^{D}(P,EP,CP), \quad \forall\, P,EP,CP\,.$$

In other words, it is always harder to resell NGC shares when the cooperative uses a discriminatory auction. This difference is greatest when the ethanol price is low.

The probability of selling in the competitive auction market is higher because buyers submit higher bid prices than they would in the discriminatory auction market. In order to be a successful seller in either market, the seller's reserve price must be below the lowest successful bid price. Since the competitive auction market bid prices are consistently higher than in the discriminatory auction market, the odds that a given reserve price will be successful are increased. Having a larger range of reserve prices over which NGC shares could legitimately be sold reduces the fear of irreversibility and increases the number of shares that are purchased in the first place.

5.3.2 Investment Thresholds

Figure 5.8 shows the investment thresholds for the representative agent in both the competitive and discriminatory auction markets. Just as in the competitive market, the agents' investment thresholds are, for the most part, well below the net present value threshold. This suggests that the benefits of diversification continue to outweigh the value of waiting even as the NGC adopts an auction trading mechanism.

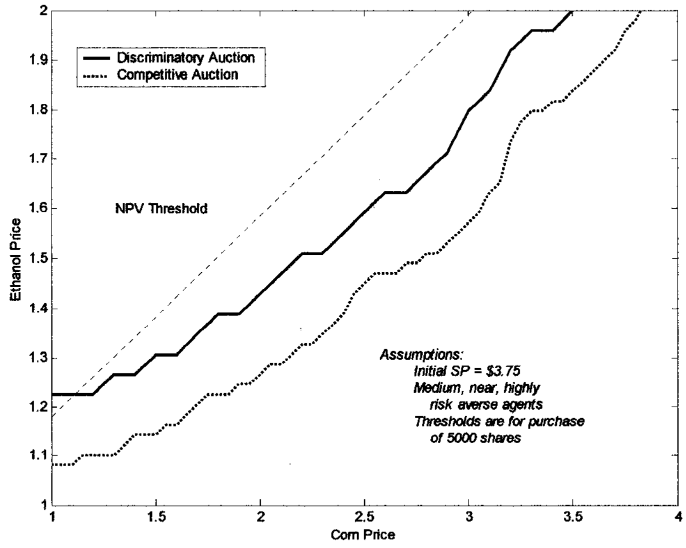

Figure 5.8
Agent Investment Thresholds

However, as the ethanol price becomes very low both investment thresholds begin bending upward toward the NPV threshold. This is because the probability of reselling becomes very low, the investment becomes less reversible, and the value of waiting becomes more significant.

The investment threshold for the agent in the competitive auction market is well below the threshold in the discriminatory auction market. This result follows directly from the discussion in the previous section. Greater irreversibility in the discriminatory auction market causes agents to temper their exposure to the NGC by offering to purchase fewer shares. More favorable market conditions (higher ethanol prices and / or lower corn prices) will be required before that agent will be enticed to purchase the same number of NGC shares he would purchase in a competitive market.

5.3.3 The Effect Of Risk Aversion

Figure 5.9 plots the optimal policy of two agents in a discriminatory auction market who differ only by their levels of risk aversion. The agent with higher risk aversion always submits a higher bid price. Being more risk averse, this agent improves his chances of success by submitting a higher price, but offsets his higher bid price by bidding for fewer shares than his less risk averse counterpart. Similar behavior occurs in the competitive auction market. Being willing to pay more for NGC shares, the highly risk averse agents in both auction markets have lower investment thresholds than the agents with low risk aversion. This is true in the competitive auction market also.

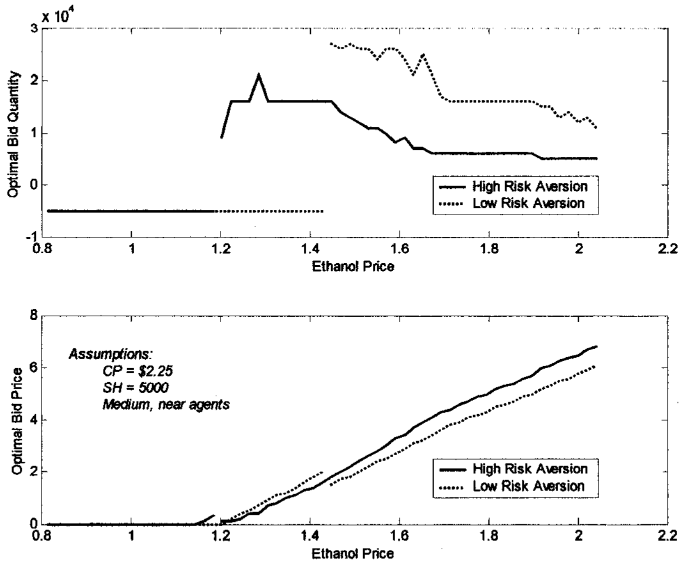

Figure 5.9
Optimal Prices and Quantities for Agents with Different Risk Aversion in a Discriminatory Auction Market

Figure 5.9 also illustrates one of the problems posed by trading with a discriminatory auction mechanism. It shows that over the range of ethanol prices from about $1.20 to $1.40, the agent with high risk aversion is a buyer and the agent with low risk aversion is a seller. However, no trade will occur because the seller's reserve price is always higher than the buyer's bid price. In fact, for every type of agent in the discriminatory auction market there is a discontinuity between the bid price function and the reserve price function, with the reserve price function being higher on its right hand endpoint than the bid price function is at its left hand endpoint. The effect is that in the discriminatory auction market it is difficult to find compatible buyers and sellers. In the competitive auction market, however, the bid price function is higher than the reserve price function at the point of discontinuity.

This results in a significant increase in trading volume in the competitive auction market (see §5.4.3).

5.3.4 The Effects Of Changes In Other Agent Characteristics

The impact of changing an agent's size and distance from the cooperative is predictable. Since a large agent has more corn available to commit to the NGC and requires a greater investment in order to realize equivalent gains from diversification, he bids for a greater quantity that his smaller counterparts. The difference in the bid prices between large and small agents is negligible. The investment threshold for the large agent is then lower.

When an agent is located farther from the cooperative the cost of delivering corn increases and the effective corn price received by the agent is reduced. Consequently, the agent who is closer to the NGC will bid a slightly higher price and a slightly greater quantity in both types of auction markets. The "near" agent will also have a lower investment threshold.

5.4 MARKET SIMULATION RESULTS

It is very difficult to model strategic behavior on both sides of the market, so analytical models of double auctions are scarce (McAfee and McMillan, p.726). However, numerical methods make it possible to solve complex auction models. In this model, agents choose both price and quantity (expanding on Tenorio 1997). Quantities can be positive or negative so each agent's role as a buyer or seller is determined endogenously and can change over time. As a result, each time period there is a set of buyers and a set of sellers (either of which could be empty) and all of the agents submit a price and quantity based upon their observation of the previous period's ethanol and corn prices and their belief about the probability their bid will be successful. The price at which aggregate supply is equal to aggregate demand is the stop-out price.[6] Successful buyers (those who bid above the stop out price) are matched randomly with the successful sellers (those with reserve prices below the stop out price) until all successful bidders have received their bid quantities. Share prices are then determined based on the rules of the respective auctions.

The simulations in the auction markets were performed in the same manner as the simulations in the perfectly competitive market. The parameters describing the probability of trading and, in the case of the competitive auction, the parameters describing the expected stop-out price were estimated and used to solve each agent's dynamic programming problem. The results were used to perform ten simulations (with 21 agents and 10 years of trading) and the outcomes were used to estimate new parameters. This process was repeated until there was no statistically significant difference in any of the parameters for two consecutive simulations[7]. At this point the agents' "expectations" matched the actual market performance. The final "rational expectation" parameters were then used to find investment and exit thresholds and perform the other experiments discussed in this section.

5.4.1 Cooperative Formation Thresholds

Figures 5.10 and 5.11 show formation thresholds for NGC's that use discriminatory auction markets and competitive auction markets. Recall that the

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[6] Since trades can only occur on $0.10 increments it is possible that there is no price where aggregate supply is equal to aggregate demand. In that case the stop-out price is the price where net demand is closest to zero. If many prices clear the market, the stop-out price in the discriminatory auction market is the average of the market clearing prices.

[7] The parameter history for both auction models is summarized in Appendix 5.1.

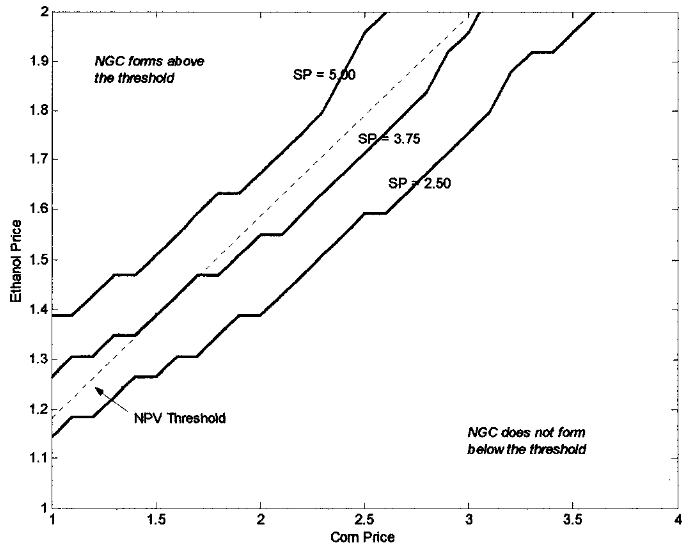


Figure 5.10
Formation Thresholds in a Discriminatory Auction Market

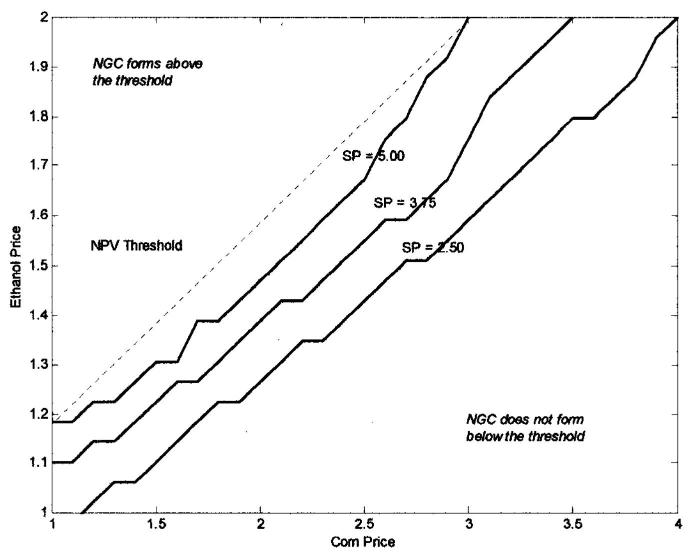


Figure 5.11
Formation Thresholds in a Competitive Auction Market

formation thresholds are the ethanol price / corn price combinations where aggregate demand is equal to the number of NGC shares available. Like the NGC using a competitive stock market, cooperatives using auction markets may also be able to form over a wide range of states where the net present value of a share[8] is well below the share price. This reflects the value of diversifying through the purchase of NGC shares.

The NGC using a discriminatory auction market has a higher investment threshold than the NGC using a competitive auction market. This is not surprising since the probability of being able to resell shares is lower in a discriminatory auction market than in the competitive auction market, adding an element of irreversibility to the investment and reducing demand for NGC shares. When all of the potential investors in a discriminatory auction NGC demand fewer shares, the cooperative will be unable to form under the same conditions as it would in a competitive auction market.

5.4.2 Share Price Dynamics

In the competitive auction market, the share price of each trade is that period's stop-out price. In the discriminatory auction market, the stop-out price is important because it determines which potential buyers and sellers will be successful in the sealed bid auction and, although the stop-out price is not necessarily the price at which trades occur, it tends to be a good approximation. In fact, the prices at which shares are traded in the discriminatory auction market are exactly equal to the stop-out price in 73.7% of all trades, and the average difference between the actual share price and stop-out price was only $0.154.

[8] In Figures 5.10 and 5.11 the NPV threshold is the threshold for a share price of $3.75. The NPV threshold for the other share prices do not differ much and have been omitted for the sake of clarity.

In both cases the stop-out price was determined in each year of every simulation and an equation of the form, $SOP = \delta_0 + \delta_1 EP + \delta_2 CP + \varepsilon$, was estimated from the simulation data. The ethanol price is in terms of dollars per bushel of corn using the 2.45 gallon per bushel conversion ration. The estimated equation for each auction type is denoted by superscript *CA* for the competitive auction and *DA* for the discriminatory auction:

$$SOP^{CA} = -1.95 + 2.63EP + (-1.99)CP + \varepsilon$$

$$SOP^{DA} = -2.31 + 2.51EP + (-1.92)CP + \varepsilon$$

All of the coefficients in each equation are significant at the 95% level. The lagged value of the stop-out price was also included in each regression, but was not significant in either case.

From the estimated coefficients of the stop-out price equation one can surmise that the stop-out price in the competitive auction is generally higher than in the discriminatory auction, but slightly more responsive to changes in the ethanol and corn prices. The results of the simulations support this conclusion. The same series of ethanol and corn prices was used to simulate each market, yet the observed stop-out price in the competitive auction market exceeded the stop-out price in the discriminatory auction market 93.6% of the time. The discriminatory auction stop-out price was typically higher when the corn price was very high. The share price that was actually paid in the discriminatory auction market trades exceeded the stop-out price in the competitive auction market only 3.6% of the time. These results suggest a higher share price in competitive auction markets, and this is consistent with the observation that buyers in the competitive auction market submit higher bid prices.

5.4.3 Trading Volume

Bid shading in the discriminatory auction market leads to buyers' optimal bid prices frequently being below sellers' optimal reserve prices (see §5.3.3). Higher bid prices in the competitive auction market, however, create more opportunities for trades to occur. The effect on trading volumes from this fundamental difference in agent behavior is predictable. The average trading volume in the competitive auction market is more than three times that of the discriminatory auction market (Figure 5.12).

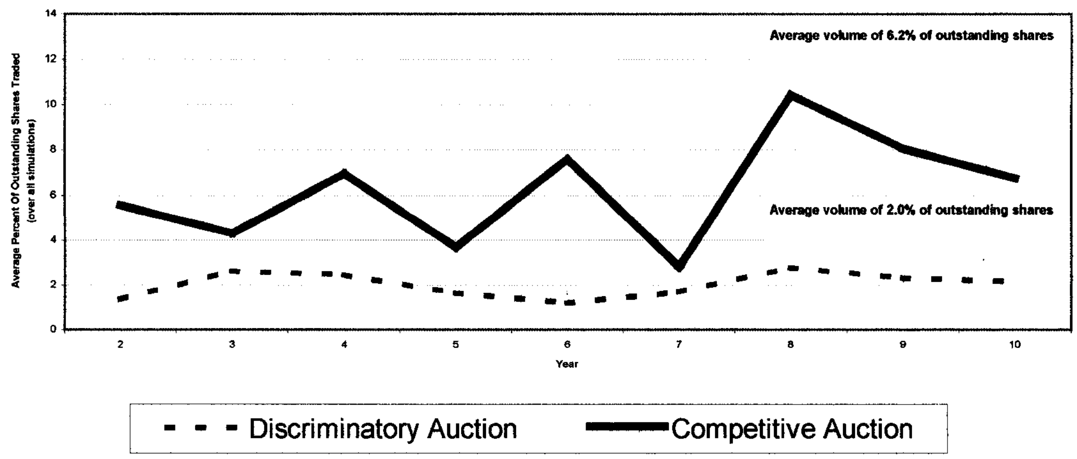


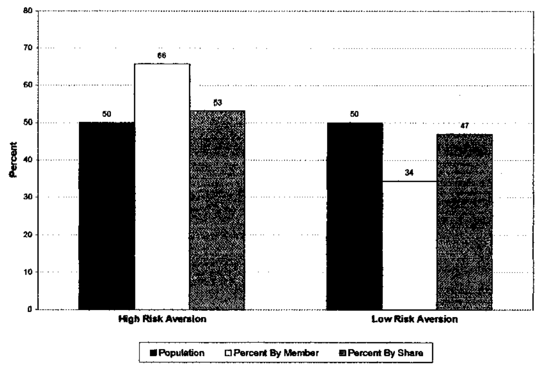
Figure 5.12
Average Trading Volumes

In the perfectly competitive market, trading volume was high immediately following the NGC's formation and then leveled off as shares were traded to the agents who valued them the most. In the auction markets, this does not appear to be the case. While the trading volume in both auction markets fluctuates, there is no discernable trend in either case. Nautz and Wolfstetter (p.200) note that when there are incentives for bid shading the auction market will not be efficient and goods may not go agents who place the highest value on them. This seems to be true for NGC's using auction markets. Although trading may not always occur in the simulated auction markets, most agents tend to submit a bid quantity and price. This suggests that few have achieved their optimal level of investment and may explain why trading volumes do not subside after the NGC has been in existence for a few years.

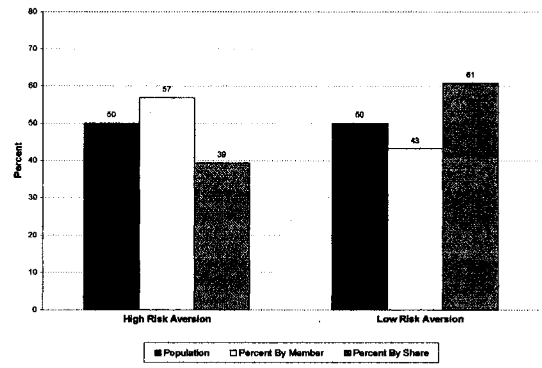
5.4.4 Membership Distribution

The distribution of membership types in the auction markets differs from that of the competitive market. Recall that the distribution of shareholders in the competitive market cooperative was predictable. The shareholders in the competitive cooperative were distributed according to the agent characteristics that result in the greatest demand for shares: large size, nearness to the cooperative, and a low level of risk aversion.

The distribution of members in the auction-type cooperatives is less intuitive. This is because an agent's risk aversion is the factor driving his success or failure in the auction setting. A highly risk averse agent tends to submit a more aggressive (higher) bid price when he is a buyer and a more aggressive (lower) reserve price when he is a seller. The other characteristics, farm size and distance from the cooperative, impact only the *quantity* submitted to the auctioneer. These characteristics tend not to be good predictors of who will own shares because an agent's success in an auction is determined solely by the *price* submitted. As a result, the shareholders in NGC's using auction trading mechanisms have disproportionately high levels of risk aversion (Figure 5.13) while the other characteristics of the cooperative's membership track more closely with the investor population as a whole.



Competitive Auction



Discriminatory Auction

Figure 5.13
Agent Distribution By Risk Aversion

When measured in terms of shares, rather than number of members, the distribution of characteristics in auction NGC's begins to look more like the competitive NGC. In both auction markets, large members own a disproportionate number of shares, although this is more pronounced in the discriminatory auction market. Agents who are located near the NGC also tend to own a higher proportion of shares than the general population. Agents with these characteristics submit higher bid quantities and so when they are successful they purchase a larger number of shares.

5.4.5 Exit Thresholds

5.4.5(a) Overview

Exit thresholds for the auction markets were derived by a method similar to that explained in Section 4.4.5(a). Assume that a potential buyer of the NGC offers to purchase all of the NGC's shares at a stated price. The problem facing the agent in an auction market is now to choose to sell all of his shares with probability of success equal to one or to sell nothing. If he chooses to sell nothing, then he assumes he will be able to buy or sell in the NGC's auction in following time periods. Under these assumptions, agents solve the Bellman equation:

$$W(EP,CP,SH) = \max_{X}\left\{\mathrm{E}\left[U[\Pi(EP',CP'|\overline{SP},X,SH,\varepsilon)]\right]+\beta\mathrm{E}\left[W(EP',CP',SH')\right]\right\}$$

subject to:

$$\begin{aligned} &CP' = CP\cdot\varepsilon^{C} \\ &EP' = EP\cdot\varepsilon^{E} \\ &\varepsilon = (\varepsilon^{C},\varepsilon^{E},\varepsilon^{S}) \\ &SH' = SH + X \\ &X = -SH \text{ or } 0 \text{ with probability} = 1 \\ &0 \le SH' \le SH_{\max} \end{aligned} \qquad (5.1)$$

The first term on the right hand side is merely a single period optimization problem with a binary choice, and the second term on the right is the continuation value function for the auction market. Since the share price is given, the problem faced by agents in the discriminatory and competitive auction markets are the same.

Just as in the competitive market NGC, if a sufficient number of members vote to sell the NGC then a takeover will occur. Again, whether there are a "sufficient" number of members voting in favor of a takeover will depend on the voting rules employed by the NGC.

5.4.5(b) Effect of Changes in the Offering Price

Figures 5.14 and 5.15 show exit thresholds for the discriminatory and competitive auction markets over a range of share prices, assuming a voting rule that requires a simple majority of the members to vote for a sale of the NGC. Members in the discriminatory auction market will consistently vote to sell the assets of the NGC

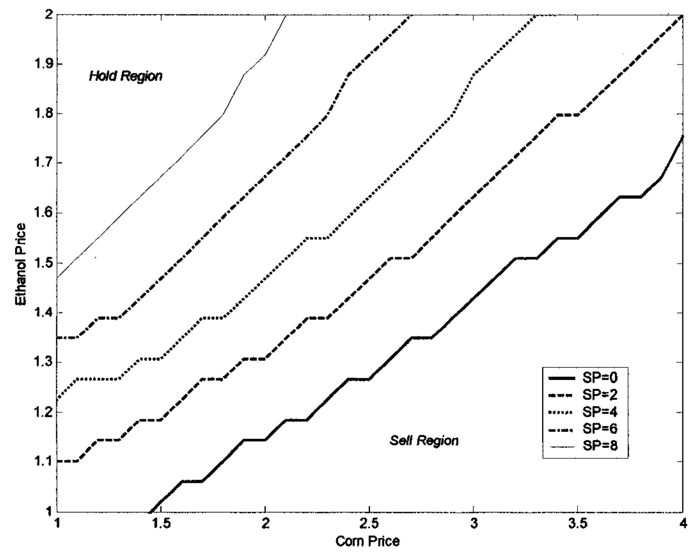


Figure 5.14
Exit Thresholds in a Discriminatory Auction Market

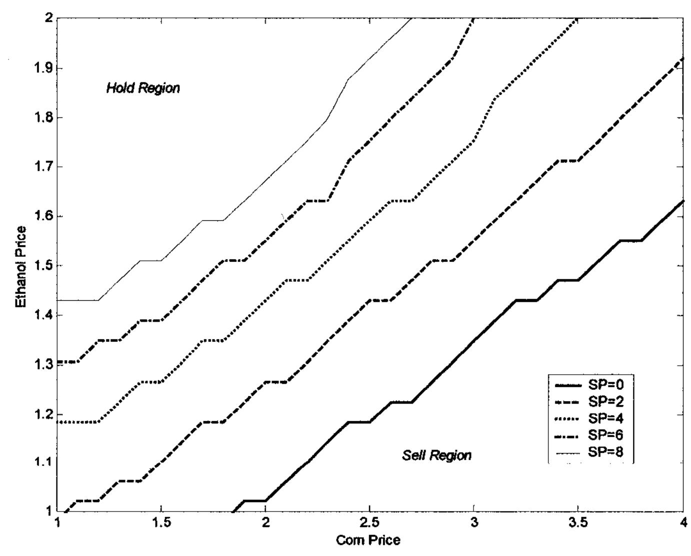


Figure 5.15
Exit Thresholds in a Competitive Auction Market

at states that are more favorable than those at which competitive auction market members would be willing to sell. These results make sense because the exit thresholds assume that voting to sell ones shares will result in a successful sale at the offering price with probability of one. The disadvantage of the discriminatory auction market is that the low probability of being able to sell shares creates an irreversibility. Therefore, when agents in a discriminatory auction market, who generally demand fewer shares to begin with, are presented with the opportunity to sell with absolute certainty, it is not surprising that they are more eager than the competitive auction market agents to take it. For the same reasons, the abandonment region (the states at which agents would vote to sell for nothing) of the discriminatory auction NGC is larger than that of the competitive auction NGC.

5.4.5(c) Effect of Changes in Voting Rules

Changes in voting rules have surprisingly little effect on the exit thresholds in the competitive market, and this is also true in the auction markets. In both auction markets, changing from a majority rule to a super-majority (two-thirds) rule has virtually no effect on the exit thresholds. Changing from member voting to share voting also has little impact. The only exception is that the exit threshold shifts upward (toward more favorable states) when the NGC is very profitable and the voting rule requires a super-majority of shares. This is because this is the only voting rule that makes it impossible to approve a sale of the NGC without substantial support from large members who are less willing to sell their shares when the NGC promises a positive return.

A significant result of this analysis is that NGC decisions will not necessarily be dictated by its large members. Prior research has suggested that large members will control cooperative policy (e.g. Staatz) because they can exert influence by threatening to leave the cooperative. However, in a NGC with a thin market for its shares a large member, who is likely be own more shares, is going to be *less* able to leave the NGC than a small agent who needs to liquidate fewer shares. The previous analysis of the member type distributions also suggests that large members will not have sufficient numbers to dominate NGC voting. As a result, small and medium sized agents may have more influence over cooperative decisions in a new generation cooperative than they would in a traditional, open membership cooperative.

5.5 CONCLUSION

This chapter analyzed agent behavior that would be induced by discriminatory and competitive auctions in new generation cooperatives. It found:

- Agents will submit higher bid prices and lower reserve prices in a competitive auction market than they will in a discriminatory auction market. This is because the manner in which prices are determined in the discriminatory auction market give agents incentive to "shade" their bids. However, the *expected* share price of agents in both auctions tends to be similar.

- Agents submit lower bid quantities in the discriminatory auction market. The discriminatory auction makes resale of NGC shares more difficult. Agents respond to this irreversibility by bidding for fewer shares initially.

- Agents with high levels of risk aversion attempt to improve their odds of success in the auction by submitting higher bid prices. They compensate for a higher expected share price by bidding for fewer shares.

- Generally, agents in discriminatory auction markets will demand more favorable states than agents in a competitive auction market before committing to investment in a NGC.

The results of the auction market simulations reflect the behavior observed in the individual agents:

- New generation cooperatives that adopt a discriminatory auction trading mechanism will tend to need more favorable states to form than an NGC using a competitive auction mechanism.

- Trading volume and share prices are both higher in competitive auction markets. The reduced incentive to shade bids in this auction setting leads to higher bid prices, which increases share prices and makes it easier for sellers to find trading partners.

- Members of NGC's that use auction trading mechanisms will be disproportionately risk averse. However, shares will tend to be distributed among members in a manner similar to that found in a competitive market.

- A NGC using a discriminatory auction market will liquidate at states more favorable than those at which a competitive auction market NGC would liquidate. Altering the voting rules does little to change the cooperatives' exit thresholds.

From the perspective of a cooperative organizer, it has become clear that the discriminatory auction trading mechanism is likely to be much less desirable than the competitive auction mechanism. Section 5.4.1 showed that discriminatory auction NGC's will require more favorable states to form than the competitive auction NGC, and Section 5.4.5 showed that it will also be more likely to dissolve. A discriminatory auction market also results in less trading volume and more uncertainty. This makes agents more reticent to invest and more likely to accept an offer to sell when the opportunity arises. Merely changing the trading mechanism to a competitive auction can help overcome these difficulties.

APPENDIX 5.1

Discriminatory Auction Market Bid and Ask Parameter History

		Intercept	Ethanol Price Parameter	Corn Price Parameter	F-Stat
First Iteration	Bid	-1.3624	2.4373	-1.5502	
	Ask	-2.0961	2.6063	-1.4668	
Second Iteration	Bid	-2.3593	2.7758	-1.8266	5.8202
	Ask	-3.0607	3.3738	-2.2245	28.72
Third Iteration	Bid	-4.2172	3.5981	-2.4415	25.304
	Ask	-3.4279	3.2069	-1.9522	4.0271
Fourth Iteration	Bid	-4.8289	3.6011	-2.3572	44.696
	Ask	-3.9739	3.2544	-1.8703	1.2357
Fifth Iteration	Bid	-5.0374	3.5739	-2.3321	12.994
	Ask	-4.1749	3.1254	-1.7099	2.1341
Sixth Iteration	Bid	-5.3585	3.6057	-2.3182	5.628
	Ask	-4.4667	3.0821	-1.5937	0.86399
Seventh Iteration	Bid	-5.8099	3.6666	-2.2964	5.5138
	Ask	-4.3715	2.9768	-1.5573	0.65803
Eighth Iteration	Bid	-5.0493	3.476	-2.3646	1.611
	Ask	-4.5109	2.9528	-1.4802	0.11556

Competitive Auction Bid, Ask and Stop-Out Price Parameters

		Intercept	Ethanol Price Parameter	Corn Price Parameter	F-Stat
1st Iteration	Bid	-5.2681	3.9454	-2.757	
	Ask	-3.2739	2.7534	-1.6985	
	SOP	-2.1503	2.5731	-1.8787	
2nd Iteration	Bid	-4.3743	3.4934	-2.4856	6.2411
	Ask	-2.9086	2.9429	-1.9785	2.3883
	SOP	-2.9186	2.6611	-1.6905	0.56743
3rd Iteration	Bid	-4.3673	4.1138	-3.3277	12.225
	Ask	-2.8556	2.7654	-1.8351	1.0177
	SOP	-2.3434	2.6547	-1.884	0.56848
4th Iteration	Bid	-3.7694	3.5246	-2.7218	5.3064
	Ask	-2.0974	2.8353	-2.1286	1.5356
	SOP	-2.3356	2.6062	-1.8202	0.059949
5th Iteration	Bid	-3.8609	3.9892	-3.3213	5.5073
	Ask	-2.4361	2.822	-2.0119	0.21212
	SOP	-1.9495	2.6284	-1.9893	0.34241
6th Iteration	Bid	-3.5483	3.6768	-2.9556	1.2532
	Ask	-1.8123	2.7972	-2.1677	0.48991
	SOP	-1.9397	2.7025	-2.0485	0.31979

CHAPTER 6

TWO APPLICATIONS OF THE DYNAMIC PROGRAMMING MODELS: Takeovers of NGC's and the Elimination of Ethanol Subsidies

6.1 THE INVESTOR-OWNED FIRM

The primary concern to this point has been the investment decisions of producers. However, one of the major concerns of new generation cooperatives is competition from investor owned firms (IOF's). This chapter begins by modeling the problem faced by an IOF and analyzing its optimal investment decision. With this understanding of the IOF investment decision it is then possible to combine the IOF model with the NGC models to explore (1) when a NGC will be susceptible to takeover by an IOF and (2) the impact on the organization of the ethanol industry from an elimination of the ethanol subsidy.

6.1.1 The IOF's Problem

The IOF's problem, as considered here, is simpler than the producer's problem. First of all, the IOF's sole purpose is to maximize expected profits from ethanol production. The IOF's decision about whether to invest in an ethanol plant is not complicated by the portfolio issues faced by a producer. Second, an IOF is assumed to be the sole investor in the ethanol plant. This implies there are no advantages to incremental investment since a partial plant produces no ethanol.

Therefore, the IOF's choice is binary -- either incur the cost of building the entire plant or wait.

In order to make relevant comparisons between the investment decisions of a NGC and those of an IOF, the following assumptions are made:

- The IOF and NGC will build the same sized plant;
- The equity cost of construction is the same ($3.75 per bushel of corn processed) in each model;
- Both the IOF and the NGC will finance half of the cost of construction and obtain the same financing terms;
- The plant's operating costs and the size of the ethanol subsidy are the same in each case; and
- The dynamics of the ethanol and corn prices are the same in each model.

Since the IOF is the sole investor in the ethanol plant it does not purchase shares in the same way that a producer buys shares in a NGC. However, by assuming that the plant size and cost of construction are the same for IOF's and NGC's, the IOF's decision to build a plant is the same as if an individual agent had exclusive rights to purchase all of the shares (SH_{max}) in the plant. If the IOF's choice variable is X, The IOF's decision can be thought of as the binary choice between $X=0$ or $X=SH_{max}$ if it has not yet invested, and $X=0$ or $X=-SH_{max}$ if it has already invested.

In the producer model, the "cost" of disinvesting had a significant impact on the producer's initial investment decision. In that model the expected cost of disinvestment depended on the producer's expectations about the NGC share price and his expectations about the probability of being able to find a buyer. In the IOF's model the cost of disinvestment is also important. However, in this case it is assumed there is no market for the ethanol plant so the cost of disinvestment is determined by the salvage value of the ethanol plant and equipment. It is assumed that the salvage value, which will be discussed in more detail later, is known to the IOF and is constant.

The IOF is assumed to be risk neutral, with a goal of maximizing the expected net value of profits over an infinite planning horizon. Using the notation from Chapter 2, the IOF's profit in time period *t* is:

$$\Pi_t = (SH_{t-1} + X_t)(EP_t - CP_t - AC) - SP_t(X_t)$$

where $AC = CAC$ is the IOF's average operating cost[1]. The IOF's Bellman equation becomes:

$$W(EP, CP, SP, SH) = \max_X \{ \mathrm{E}[\Pi(EP', CP' \mid SP, SH, X, \varepsilon)] + \beta \mathrm{E}[W(EP', CP', SP', SH')] \}$$

subject to:

$$CP' = CP \cdot \varepsilon^C$$
$$EP' = EP \cdot \varepsilon^E$$
$$SP = \begin{cases} \text{Construction Cost} / \text{Bu. processed} & \text{if } SH = 0 \\ \text{Salvage Value} / \text{Bu. processed} & \text{if } SH = SH_{\max} \end{cases}$$
$$\varepsilon = (\varepsilon^E, \varepsilon^C, \varepsilon^S)$$
$$SH' = SH + X$$
$$SH' = 0 \text{ or } SH_{\max}$$

[1] As a reminder, *SH* is the number of shares owned, *X* is the choice variable, *EP* is the ethanol price, *CP* is the corn price, and *SP* is the price of a share.

6.1.2 The Investment Threshold

The IOF's investment threshold can be determined by setting $SH=0$ (no investment has occurred) and solving the Bellman equation for the full set of states (ethanol price / corn price combinations) using the numerical methods of previous chapters. The set of states where the optimal investment strategy for the IOF is $X = SH_{\max}$ represents the investment region. The set of states where the optimal policy is $X = 0$ represents the region where the IOF would not be willing to invest. The investment threshold is the set of states that divides these two regions.

Figure 6.1 shows the IOF's investment thresholds for salvage values of $0, $1.50 and $3.00 per bushel of corn processed. The IOF investment threshold in all three cases is above the net present value threshold. There are two reasons for this. First, there is uncertainty over the corn and ethanol prices which make it desirable to wait and see what will happen in subsequent time periods. This is a straightforward application of the principles discussed in Chapter 3. In addition, there is value to waiting if the investment is at all irreversible. If it is costly for the IOF to change its mind and disinvest from the ethanol plant, then the IOF is more likely to wait for prices that make disinvestments unlikely or that promise sufficient profits to make up for any costs of disinvestment.

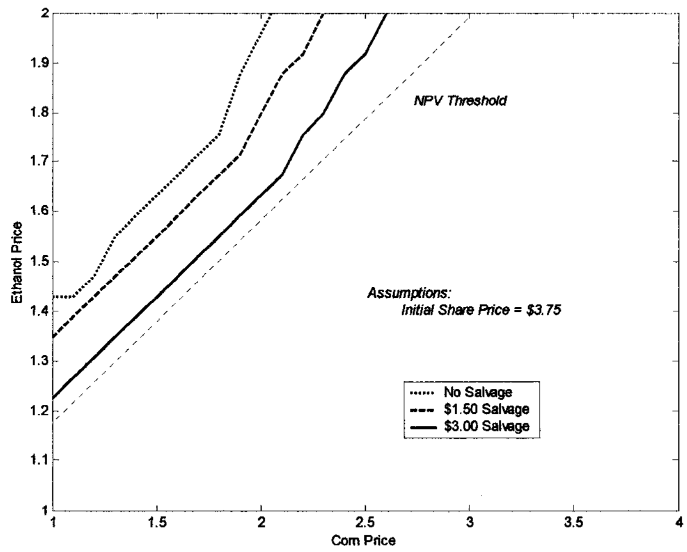


Figure 6.1
IOF Investment Thresholds for Various Salvage Values

For the IOF, the cost of disinvestment is determined by the assumptions regarding the salvage value. Figure 6.1 illustrates that as the salvage value approaches the investment cost ($3.75 per bushel processed) the investment threshold falls toward the NPV threshold. This is because a higher salvage value implies a more reversible investment decision. In other words, when it is less costly to shut down an operating plant the IOF will be more willing to invest in the first place. When little or none of the investment cost can be recouped the IOF will invest only when the ethanol plant promises significant profitability in the short term.

An important question is whether a NGC or an IOF will be more eager to start an ethanol plant. Figure 6.2 suggests an answer. It shows the investment threshold for an IOF relative to the investment thresholds of the NGC's[2]. In all cases, the IOF

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[2] It is assumed that the initial cost of investment for investors in each type of organization is $3.75 per "share." The salvage value for the IOF is assumed to be 30% of the initial cost of investment ($1.12).

investment threshold is above the investment threshold for the NGC. This implies NGC's will be more likely than IOF's to form, which is consistent with what has happened in Minnesota. The reasons for this can be described in terms of the value of waiting and the benefits of diversification discussed in Chapter 3.

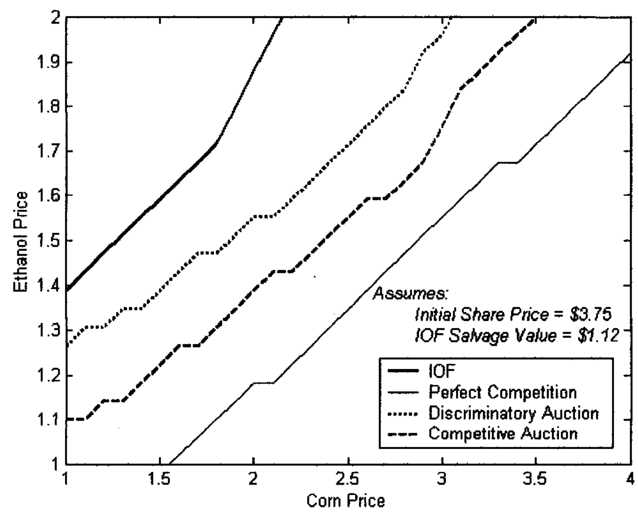

Figure 6.2
IOF Investment Threshold in Relation to NGC Thresholds

If the value of waiting (Chapter 3) were the only force at work, the NGC thresholds would be *higher* than the IOF threshold. This is because the IOF is risk neutral while NGC investors are assumed to have various levels of risk aversion. Section 3.2.1 shows that an increase in risk aversion will increase the value of waiting and push the agent's investment threshold upward toward more favorable states. Therefore, investors in a NGC should demand more favorable states than the IOF before investing. Another factor affecting the value of waiting is the cost of disinvesting. For NGC investors the cost of selling one's shares depends on the market for the NGC stock. For the IOF, the cost of disinvesting depends on the difference between the cost of investment and the fixed salvage value and the discount rate. The relative reversibility of the investments depends on salvage value assumptions and the corn and ethanol prices. Therefore, the IOF's higher investment threshold cannot be explained by a greater value to waiting.

The IOF investment threshold is higher than the NGC investment thresholds because the IOF gains no benefit from diversification. While NGC investors might place a significant value on being able to diversify their portfolio, thereby reducing the risk of corn price fluctuations, the IOF is risk neutral and is not concerned with diversification. So while the benefits of diversification drive the NGC investment thresholds down (§4.3.2), they have no effect on the IOF investment threshold. The result is that the IOF's threshold is above the NPV thresholds.

6.2 APPLICATION ONE: TAKEOVERS OF NGC'S

The purchase of the Minnesota Corn Processors (MCP) ethanol cooperative by Archer-Daniels-Midland (ADM)[3] has received considerable attention among cooperative observers. MCP's business involved more than the production of ethanol, including the production of high fructose corn, that could have caused its problems. However, most cooperative advocates have lamented the loss of such a prominent new generation cooperative and the transaction has raised important questions about the stability and, more generally, the function of new generation cooperatives in the ethanol industry. For example, should the sale of MCP to ADM be considered a failure, an aberration, or the inevitable consequence of the NGC organizational form?

[3] The sale is currently on hold due to antitrust concerns raised by the Justice Department.

In this section, the lessons and methods of the previous chapters will be applied to the issue of IOF takeovers of NGC's. The question initially appears to be a difficult one. The previous analysis suggests producer demand for shares in an ethanol cooperative will be higher than demand in the same plant by an IOF. It is not obvious from that analysis why members of a NGC would eventually decide to sell all of their shares at the same time an IOF was willing to buy them.

The answer, however, can be traced to the different objectives of the producers and the IOF. Specifically, when the corn price is low it is also less volatile so NGC members will feel less need to diversify their portfolios by holding shares in the NGC. However, for the risk-neutral IOF a low corn price implies higher profits. As a result, there is a set of corn price /ethanol price combinations at which an IOF may be willing to purchase the ethanol plant and the NGC members may be willing to sell. The exact nature of this "takeover region" depends on the structure of the NGC.

6.2.1 Determining the Takeover Regions

A "takeover region" is a set of corn price / ethanol price combinations at which the maximum price an IOF would be willing to pay for the shares and debt of an existing ethanol cooperative is higher than the lowest price at which a sufficient number of NGC members would be willing to sell. Finding this takeover region requires only a slight modification of the entry and exit threshold analysis discussed in previous sections.

The IOF's investment region was previously defined as the set of ethanol price / corn price combinations at which it would be willing to purchase all of the shares of an ethanol plant for $3.75 per share. In other words, the investment threshold was found by solving the Bellman equation at a fixed share price and a current share balance of zero. When the IOF is considering the purchase of an existing NGC, the share price becomes stochastic. The investment threshold is found by solving the Bellman equation for every possible share price, and the highest share price at which the solution at a given state is $X = SH_{\max}$ represents the most the IOF would be willing to pay NGC members for their shares at that state. By doing this at every possible state it is possible to get a matrix of share prices (call this matrix BUY^{IOF}) that represents the most the IOF would be willing to pay for the NGC shares at every possible state.

A similar method can be used to find the lowest price NGC members would be willing to accept in order to sell the cooperative to the IOF. Sections 4.4.5(a) and 5.4.5(a) discuss the methods for determining whether NGC members would vote to sell all of the shares in a cooperative. By solving that problem for every possible state and over the complete range of possible share prices it is possible to construct another matrix representing the lowest share price the NGC would accept in a takeover bid (call this matrix $SELL^{NGC}$).

A NGC would presumably have the same opportunity as an IOF to sell its ethanol plant for salvage. However, this model assumes the NGC could accept a price from IOF that is less than the salvage value. The reason is that a NGC finances about half of the cost of constructing its plant and this debt will undoubtedly be secured with the NGC's plant and equipment. If the NGC sold the plant for salvage, the proceeds would go the bank unless the loan had been substantially paid off. From a member's perspective, selling the plant for salvage is the equivalent of receiving nothing for his shares[4]. He would consequently prefer to sell his shares to an IOF which would assume the debt and continue operating the ethanol plant.

The takeover region for a NGC is the set of ethanol price / corn price combinations where the maximum the IOF is willing to pay is greater than the minimum the NGC members are willing to accept. At these states there are potential gains from trade if an IOF purchases the NGC. Assuming no prohibitive transaction costs, a takeover is most likely to occur in those states.

6.2.2 Takeover Of A NGC Using A Discriminatory Auction

6.2.2(a) Takeover Region

Figure 6.3 shows takeover regions for a NGC using a discriminatory auction trading mechanism. There are four non-empty takeover regions, each representing a different voting rule. The takeover regions are concentrated in states where both the corn price and ethanol price are low, and all of the takeover regions are completely contained in the set of states below the NPV threshold.

To explain this, first consider the states at which takeovers will not occur. When the ethanol price is high and the corn price is low (the northwest corner of the graph) the ethanol plant is profitable and promises both a positive return and some diversity for the portfolios of NGC members. It is not surprising that producers are

[4] An IOF would also need to satisfy its debt in the event the plant was closed. However, satisfaction of the debt is valuable to the IOF which holds the ethanol plant as part of a larger portfolio and would not want to file bankruptcy in order to avoid paying the debt.

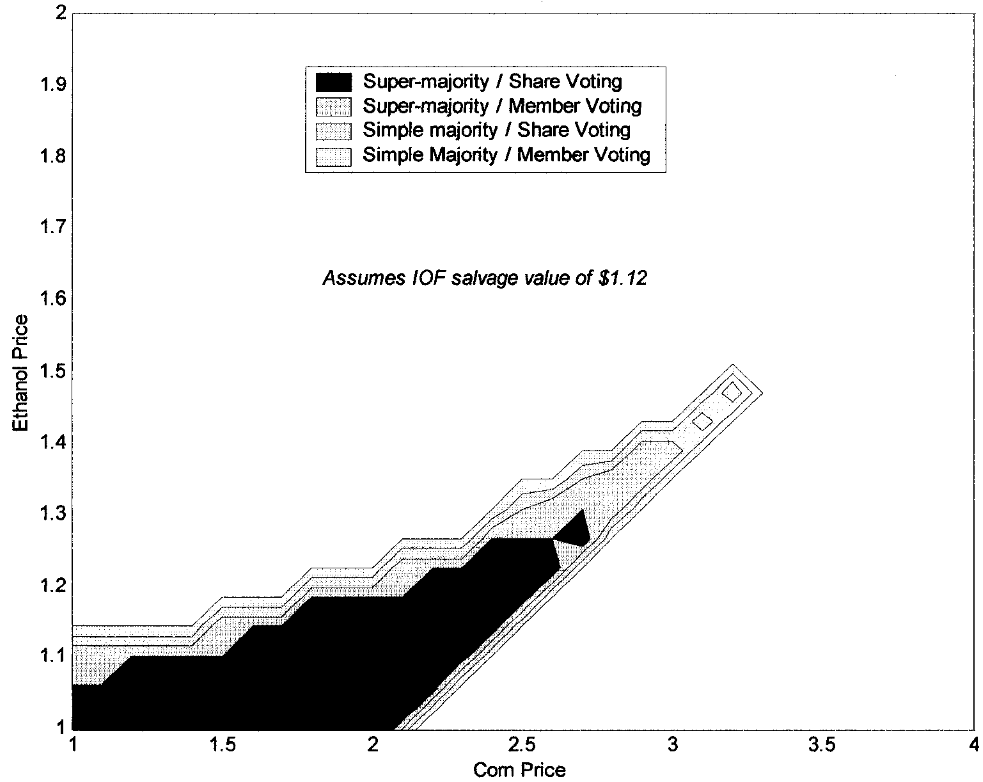

Figure 6.3
Takeover Region for NGC Using a Discriminatory Auction Market

unwilling to sell their shares when the state is in this range. When the ethanol price is low and the corn price is high (the southeast corner of the graph) the ethanol plant is very unprofitable and one would not expect the IOF to offer to buy it at even the lowest price. Therefore, the interesting states are those along the diagonal where the ethanol price and corn price are such that the net present value of future returns from operating the ethanol plant are close to zero.

The presence of a takeover region and its location in the southwest corner of Figure 6.3 can both be explained by the fact that producers invest, in part, to diversify while IOF's do not. When the ethanol plant's profits are near zero, the risk-neutral

IOF is indifferent between the situation where both the corn and ethanol price are low and the situation where they are both high. The IOF cares only about the difference between the two since that is all that effects profitability. This is not the case for NGC investors. As the corn price gets higher the corn price volatility also becomes greater. This leads a risk averse investor to demand more shares of the NGC in order to diversify his portfolio. When the corn price drops it becomes less volatile and the value of diversification is reduced. Consequently, while the IOF is indifferent between states along the southwest to northeast diagonal the NGC investor is more willing to sell his shares at the southwest end of the diagonal. As a result, a slightly unprofitable ethanol plant coupled with a low corn price present a prime opportunity for IOF's to purchase a NGC's shares.

The ADM / MCP transaction is consistent with this prediction[5]. Negotiations over the sale became public in May, 2002 (Business Journal) when the corn price was slightly less than \$2.00 per bushel and the ethanol price was \$0.98 per gallon (MN Dept. Agric.). In September 2002, 81% of the MCP members voted to sell their shares. By that time the corn price had risen to nearly \$2.50 per bushel and the ethanol price rose to \$1.26 per gallon. The ethanol price / corn price combination at the date of both these milestones were in the takeover region described in Figure 6.3.

6.2.2(b) Takeover Prices

Comparing the BUY^{IOF} and $SELL^{NGC}$ matrices not only helps identify the takeover region but it can suggest a range of share prices at which the sale might

[5] MCP does not provide a perfect comparison because it had converted to a limited liability company two years before the sale to ADM. However, MCP stock retained some characteristics similar to those of a NGC so a comparison to the ADM / MCP deal is instructive.

occur. Figure 6.4 shows contour lines over the takeover region that represent the average between the highest price the IOF is willing to pay and the lowest the NGC is willing to accept for its shares. This figure predicts that an IOF will purchase a NGC only if the share price is very low[6]. This is not surprising because the takeover region falls in the range of states where the ethanol plant is unprofitable. NGC members are faced with the unenviable dilemma of owning shares in a cooperative that is losing money and providing little benefits of diversification. On top of that, to disinvest they must sell their shares in a thin market in which nearly all of the other members are also trying to sell. These three factors all push down the share price to the point where purchase of those shares becomes attractive to an IOF, which can purchase the ethanol plant for a fraction of the cost of a new plant.

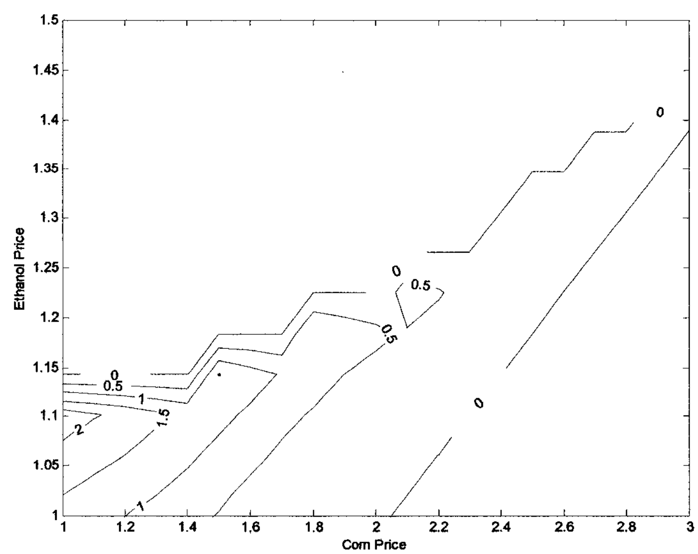

Figure 6.4
Expected Takeover Prices for a Discriminatory Auction NGC Using a Simple Majority / Member Voting Scheme

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[6] At the time the ADM / MCP sale was approved by shareholders, MCP stock was trading at $1.00 per share. ADM offered shareholders a generous $2.90 per share for the stock.

6.2.3 Takeover Of A NGC Using A Competitive Auction

Figure 6.5 shows the takeover regions for a NGC using a competitive auction trading mechanism. The takeover regions for this NGC are much smaller than for the discriminatory auction. The incentives for the IOF have not changed but, as discussed in Chapter 5, the competitive auction NGC provides a more liquid market for NGC shares and higher share prices. Simply, under a competitive auction regime NGC members have more opportunities to trade shares among themselves and will

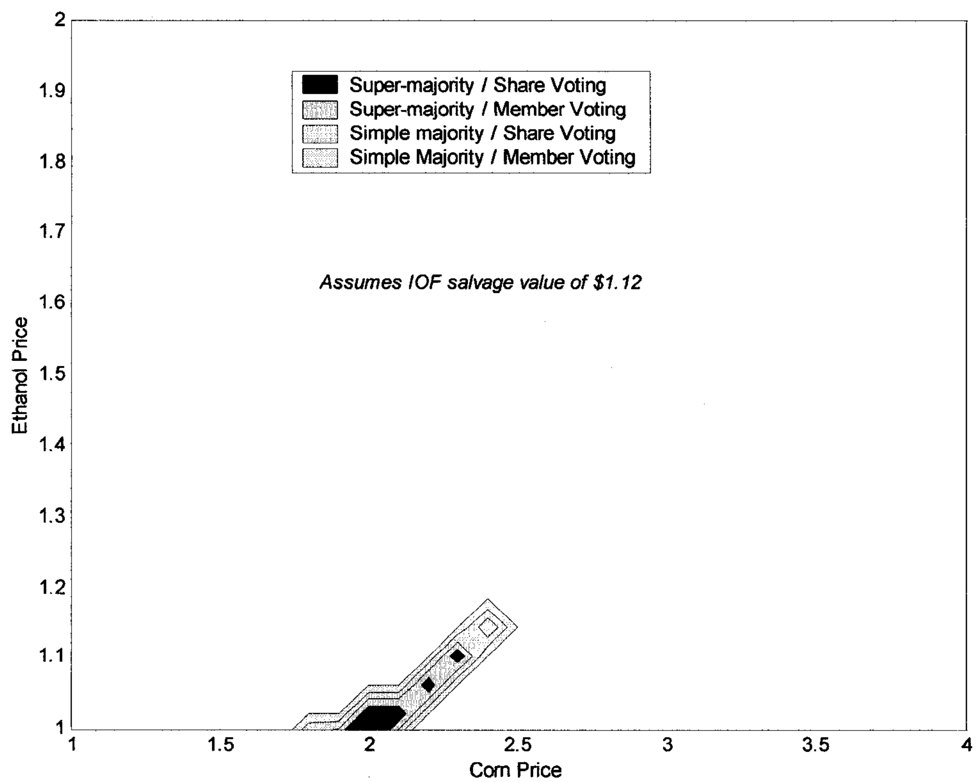

Figure 6.5
Takeover Region For NGC Using A Competitive Auction Market

consequently demand a higher price from the IOF. Only in limited circumstances where the market for shares among producers has dried up will the NGC members agree to sell to the IOF.[7]

6.2.4 Takeover Region For NGC With A Perfectly Competitive Market

When a NGC has the luxury of a perfectly competitive market for its shares, there is no takeover region. A perfectly competitive market is liquid enough that producers are able to trade shares even when the corn price is low. Under these circumstances, there is no need for NGC members to sell their shares to an IOF.

6.3 APPLICATION TWO – THE REMOVAL OF ETHANOL SUBSIDIES

6.3.1 Overview of Subsidies

The production of ethanol is heavily subsidized in Minnesota. Chapter 1 explained that the federal government provides ethanol producers with significant tax breaks and credits and the State of Minnesota further subsidizes ethanol producers. Currently, Minnesota pays ethanol producers in the first ten years of operation $0.20 per gallon of ethanol for the first 15 million gallons produced (Minn. Stat. §41A.09). As a result of these subsidies and tax advantages, an estimated twelve percent of an ethanol plant's total revenue is derived from state and federal assistance (Tiffany, 2002).

It is unclear how much longer these subsidies will continue. After discussions of substantially reducing or eliminating the Minnesota subsidy, the 2003 Minnesota

[7] When a takeover of a competitive auction NGC does occur, the expected share prices ranged from $0.05 to $0.70.

legislature finally agreed to change the criteria and timing of ethanol payments to effectively reduce the total subsidy payments by one-third. (MN Dept. Finance; Minn.Sess.Laws (2003), Ch.128, §38). Current budget problems and tepid popular support for the subsidy suggest further cuts are possible. This section examines the impact of changing the level of subsidization of ethanol plants.

6.3.2 Impact of Subsidies on Initial Investment

The goal of this section is to look at the impact of eliminating ethanol subsidies on initial investment. Eliminating the subsidies is akin to increasing the average cost of production and reducing average profit. One would expect this to cause investors to demand more favorable corn and ethanol prices before investing and, in fact, the model predicts this outcome. The more interesting questions are, (1) how much do the investment thresholds change, and (2) do the thresholds for each of the organizational types change in the same way? Application of the dynamic programming models predicts that eliminating the ethanol subsidy will have a greater impact on the IOF's investment threshold then it will on any of the NGC's.

Up to this point, the model has incorporated an ethanol subsidy equal to $0.21 per bushel of corn processed. For this section, the subsidy is set at zero, effectively increasing the average cost of production by $0.21 per bushel. The method for determining formation thresholds with no subsidy is the same as with the case of a full subsidy. For each of the four organizational types (the three NGC's and the IOF) the subsidy was eliminated, new rationally expected share prices and trading probabilities were calculated using the iterative methods described in previous chapters, and new investment thresholds were calculated by aggregating the optimal investment decisions of individual agents.

Figure 6.6 shows each organization's investment threshold with and without the subsidy. Each situation assumes an initial share price of \$3.75 and the IOF model continues to assume a salvage value of \$1.12. These figures confirm the prediction that eliminating the subsidy increases the investment threshold for each type of firm. However, it also shows that the impact on the IOF is greater than it is for any of the NGC's. It also implies that the NGC's stock trading mechanism will influence how the NGC responds to an elimination of the subsidy.

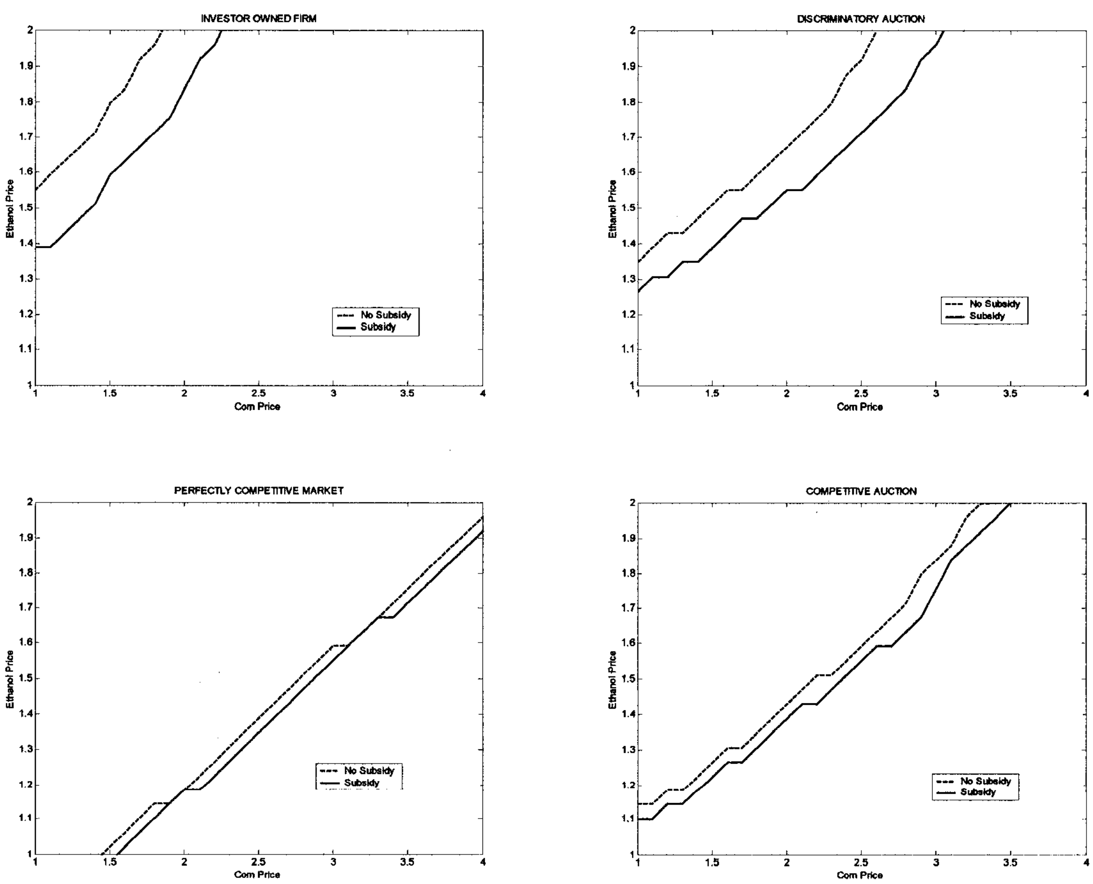

Figure 6.6
Change in Investment Thresholds Due to Elimination of the Ethanol Subsidy

The easiest way to understand these differences is to start with the IOF. There are two components to the shift in the IOF investment threshold; a reduction in the net present value of the investment and an increase in the value of waiting. The first results from the net present value threshold shifting upward by the amount of the subsidy[8]. However, the investment threshold for the IOF shifts upward by a magnitude of about 1.5 times the size of the subsidy reduction[9]. This is because taking account of the value of waiting implies the investment threshold for the IOF will be higher than the NPV threshold by some factor, β, which is greater than one (equation 3.8). Therefore, eliminating the subsidy also increases the value of waiting and this accounts for the remainder of the shift in the IOF investment threshold.

Figure 6.6 shows that the investment threshold for each of the NGC's shifts less than the threshold for the IOF. This is explained by the benefits of diversification offered by the NGC. Chapters 4 and 5 showed that the benefits of diversification have a much greater impact on investment in NGC's than the value of waiting. So while the elimination of the ethanol subsidy reduces the net present value of the investment for NGC investors, just as it does for the IOF, the benefits of diversification remain very much intact. The net result is that the impact on the NGC investment threshold is tempered by the value of diversification, which remains

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[8] Change the notation of Chapter 3 slightly to reflect that the firm's profit includes revenues and costs = $(P\text{-}C)$. Then, $NPV = SH'(P-C) + \frac{SH'(P-C)}{\rho}$. Setting this equal to the share price and solving for P yields the new net present value threshold: $P = SP\frac{\rho}{\rho+1} + C$.

[9] For a given corn price, the new investment threshold is about \$0.15 per gallon of ethanol higher than the threshold with the subsidy. When converted into \$ / bushel, the difference is about \$0.35 per bushel. This is larger than the \$0.21 / bushel reduction in the subsidy.

largely unaffected, and so the shifts in the NGC investment thresholds are less dramatic than for the IOF.

Eliminating the ethanol subsidy shifts the investment threshold for the discriminatory auction NGC upward nearly as much as that of the IOF, while the threshold for the NGC that attains a competitive market shifts hardly at all. These differences are due to market thinness. Recall that the discriminatory auction NGC has the least liquid market for its stock. Eliminating the subsidy effectively increases the cost of operating the ethanol plant, reduces the NGC's profit, and makes the stock less desirable so there are fewer potential buyers in the market. As a result, the market becomes thinner and the investment becomes less reversible (*see* §5.3.1(b)). A comparison of the rationally expected buy and sell parameters between the model with a subsidy and the model without reveals that the expected probability of being able to execute a trade at any given state drops when the subsidy is eliminated. This is true in each of the auction models.

A less liquid stock market implies that much of the upward shift in the investment threshold for the discriminatory auction NGC is due to an increase in the irreversibility of the investment. Eliminating the subsidy for the competitive auction NGC also increases irreversibility but, for the reasons discussed in Chapter 5, the effect is less than in the discriminatory auction market and the investment threshold has a smaller upward shift. The perfectly competitive NGC has a perfectly liquid market for its stock and does not experience any increase in irreversibility. Therefore, its investment threshold moves only slightly.

The end result of eliminating the ethanol subsidy is that all of the organizations will require more favorable states before forming. However, the impact on the IOF is greater than it is on the NGC's. An unexpected result is that removing the subsidy will create a wider range of states over which a NGC will be likely to form without interference from an IOF. Eliminating the subsidy will probably reduce the number of new ethanol plants, but those that do form are more likely to be cooperatives.

6.3.3 Impact of Subsidy Reduction On Existing Firms

The previous section looked at how investment in new ethanol plants would change if the ethanol subsidy were eliminated. However, there are currently fourteen ethanol plants in Minnesota, eleven of which are owned by cooperatives. The impact on these existing plants may have greater political and economic importance than the effect on future investment. This section examines the effect on existing plants from eliminating the ethanol subsidies.

The models of previous chapters were used to simulate the removal of the ethanol subsidy in year three of a plant's existence. Just as in previous chapters, twenty-five different ten year simulations were performed, with each agent trying to implement his optimal investment strategy by buying or selling share in his NGC. As usual, agents' optimal decisions were found by solving the Bellman equations. In years one and two of the simulations the average cost parameter included a $0.21 per bushel subsidy, while agents' optimal decisions in years three through ten were based upon an average cost parameter that did not include the subsidy. In other words, the simulated ethanol plants were formed with a subsidy in place and the subsidy was suddenly removed, without the prior knowledge of the agents, in year three. The results of the simulations were used to analyze the resulting distribution of agent types and to determine new exit thresholds.

Eliminating the ethanol subsidy has very little effect on the volume of NGC stock traded and causes very little change in the nature of the NGC membership (*see* Appendix 6). There is no discernable difference in the volume of shares traded in any of the NGC's, and although it was expected that there would be a jump in trading volume in the time periods immediately after the elimination of the subsidy no such jump is observed. Neither is there a significant change in the characteristics of NGC members after the elimination of the subsidy. Both of the auction-type NGC's evidence some trend toward members who are less risk averse and located closer to the ethanol plant, *i.e.* the membership began to look more like the membership of a NGC with a perfectly competitive market, but these changes are small. These results are consistent with previous observations that members' desire to diversify mutes the impact of the ethanol subsidies.

Figure 6.7 shows the exit thresholds for the discriminatory auction and competitive auction NGC's with and without subsidies, assuming a reasonable offer price of $2.00 per share[10]. The exit thresholds shift upward when the subsidy is removed for the same reasons the investment thresholds shift upward. The ethanol plant is less profitable and the investment is less reversible so members are willing to sell their shares under more favorable market conditions. In fact, since the nature of

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[10] The position of the exit thresholds changes as the offer price changes, but the relative positions of the exit threshold with the subsidy and the exit threshold without the subsidy do not change.

the membership and the volume of trading are relatively unchanged after removal of the subsidy, the exit thresholds shift by about the same magnitude as the shift in the investment threshold. As expected, the NGC achieving a perfectly competitive market had a very small upward shift in the exit threshold. Therefore, taking the subsidy from an existing ethanol plant affects demand for shares about as much as it does for investors in a prospective NGC and, as a result, has very little impact on the make-up of the NGC membership.

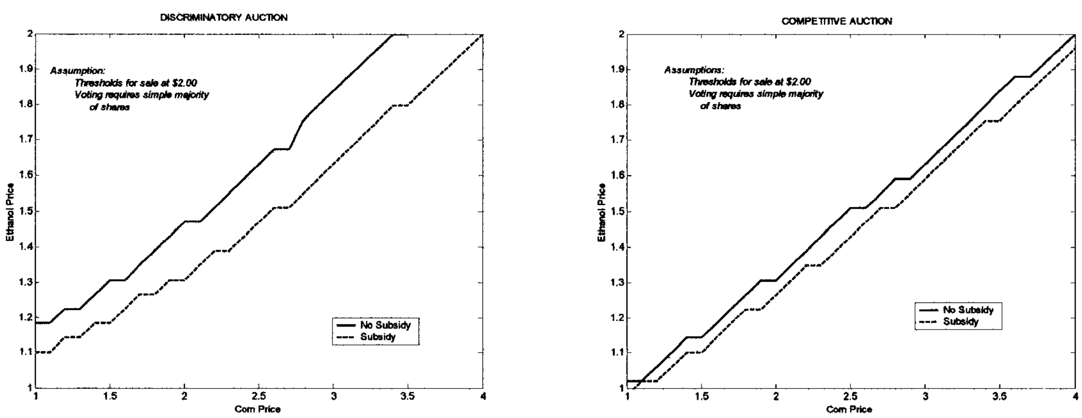

Figure 6.7
Impact on Exit Thresholds from the Elimination of Ethanol Subsidies

6.3.4 Effect on NGC Stability

The results of the previous two sections can be used to predict how removal of the ethanol subsidy would affect NGC stability.

The takeover regions for the NGC's shrink when the ethanol subsidy is removed. The IOF's investment threshold is driven up when the subsidy is removed (§6.3.2). In general, this means the IOF is willing to pay less for stock in a NGC. The exit thresholds for the NGC's, however, rise considerably less than the IOF's investment threshold due to the tempering effect of the value of diversification (§6.3.3). In other words, the price NGC members are willing to accept goes down less than the price an IOF would be willing to offer. As a result, there is a smaller range of states over which the IOF would be willing to pay a price that would induce the NGC members to sell their shares. When the subsidy is eliminated the takeover region for the discriminatory auction NGC in Figure 6.3 shrinks to about one-eighth of its previous size and the takeover region for the competitive auction NGC shown in Figure 6.5 disappears completely.

While eliminating the subsidy reduces the chance of an IOF takeover, it also increases the chance the NGC members will abandon the cooperative. With the increase in the NGC exit threshold also comes a larger "abandonment region." This means there are more states where members are willing to sell all of their shares for $0.

6.3.5 Conclusion

Eliminating ethanol subsidies lowers profits for investors, whether it be an IOF or producers investing in a NGC, but there are still many states where the construction of an ethanol plant would be beneficial. For new generation cooperatives, losing the subsidy makes it more difficult for NGC's to form but it also reduces the chance that an IOF would enter the market first. In other words, there are likely to be fewer new ethanol plants, but those that are built are more likely to be NGC's.

Eliminating the ethanol subsidy may also have the unexpected effect of reducing the number of NGC's that are taken over by an IOF. The subsidy is likely to be much more important for the IOF than it is for the NGC investors, so eliminating the subsidy will make the NGC ethanol plant a much less desirable takeover target. On the other hand, without the opportunity to sell the ethanol plant to an IOF it is more likely that NGC members will simply close the plant without a sale.

6.4 CONCLUSION

This chapter first created a model of investment in an ethanol plant by an investor-owned firm and then used that model, as well as the models in previous chapters, to look as some pertinent policy questions.

It may be beneficial for an IOF to invest in an ethanol plant, but the IOF's investment threshold will be above the net present value threshold and well above the investment thresholds of the NGC's. While the IOF faces the same profit uncertainty as investors in a NGC the IOF does not get the benefit if diversification enjoyed by producers and, consequently, will demand greater profitability before it will be willing to build a new ethanol plant.

The second part of the chapter applied the NGC investment models and the IOF investment model to the issue of IOF takeovers of NGC's and the question of the impact of ethanol subsidies. First, takeovers of NGC's are most likely to occur when the ethanol price and the corn price are both low. This is because IOF's care only about profit so are indifferent between high ethanol and corn prices and low ethanol and corn prices so long as the difference between the two is the same. NGC investors, on the other hand, lose some benefit of diversification when the corn price is very low and so are more eager to sell in that situation. The result is that takeovers are most likely when the ethanol plant is slightly unprofitable and the corn price is low.

Second, it is predicted that the elimination of ethanol subsidies will have a greater impact on the IOF than on the NGC investors because IOF's do not care about diversification, a benefit that remains intact for NGC producers even when the subsidy is removed. This conclusion has a number of implications:

- Removing the ethanol subsidy would result in fewer ethanol plants but those that would form would most likely be NGC's.
- An existing NGC would be less likely to be taken over by an IOF after elimination of the ethanol subsidy.
- Without an ethanol subsidy, an existing NGC would be more likely to be abandoned by its members.

CHAPTER 7

CONCLUSION

7.1 SUMMARY OF RESULTS

Member-owned firms have become increasingly prominent in many industries, including the ethanol industry. Despite an upsurge in the popularity of member-owned firms, especially the new generation cooperatives (NGC's) that now dominate Minnesota's ethanol industry, there has been little research directed toward understanding why NGC's might proliferate in one industry while investor-owned firms are more prevalent in others. In this study, dynamic programming techniques have been used to better understand the investment decisions of cooperative members, and consequently the entry and exit patterns of NGC's.

There were three main objectives in this study. The first was to analyze producer investment in a new generation ethanol cooperative. The second was to model the market for stock in NGC's under various assumptions about the stock trading mechanism and to explore the investment and disinvestments decisions of members and the cooperative under each assumption. The third was to apply the model to two policy issues that are currently important to the ethanol industry: the threat of takeover of NGC's by investor-owned firms and the impact of the ethanol subsidy on the formation and stability of ethanol plants.

The general model and its parameters are outlined in Chapter 2 and two of the major features of the model, the value of waiting and the benefit of diversification, are discussed in Chapter 3. The most significant point of these sections is that the traditional net present value rule of investing does not provide an adequate model of investment when volatile prices make returns uncertain and when an investment provides significant diversification benefits.

One of the keys to understanding investment in NGC's is to recognize that the value of waiting and the benefits of diversification have opposite effects on the demand for investment. It was shown that when the corn and ethanol prices are volatile and follow non-stationary processes there is a positive value to delaying investment *(i.e.* waiting) while some price uncertainty is resolved. This value of waiting increases as prices become more volatile. On the other hand, a corn producer's desire to diversify his portfolio will increase the incentives to invest in a NGC and may make it beneficial to invest even when the NGC is unprofitable.

Whether demand for a certain NGC's stock is greater or less than that predicted by the net present value rule depends on which effect is stronger. In Chapters 4 and 5 it was shown that for a risk-averse producer of corn the benefits of diversification exceed the value of waiting, given the assumptions used in the study. Consequently, an agent's true "investment threshold" is often well below the investment threshold predicted by the traditional net present value rule.

The second objective, modeling NGC entry and exit thresholds, was accomplished by aggregating the investment decisions of all potential cooperative members. New generation cooperatives differ from traditional cooperatives in that NGC's sell tradable stock. It was found that the method by which the stock is traded has an effect on the value of the stock, the liquidity of the stock, and ultimately the ability of the cooperative to form and survive. Chapter 4 analyzes a NGC that is able to maintain a competitive market for its stock. Chapter 5 expands the model to include NGC's that use two types of multi-unit, sealed bid, double auctions to trade stock: (1) a discriminatory auction in which each buyer pays his bid price and (2) a competitive auction where every trader pays a common market-clearing price.

To analyze the nature of the market for NGC stock under each trading regime, multiple market simulations were performed after determining rational expectations for share prices and trading probabilities. When individual agents have rational expectations about the NGC share price and the probability of being able to execute a trade, changing the stock trading mechanism also changes agents' optimal investment policies. Most significantly, agents in discriminatory auction markets will demand the most favorable states (*i.e.* a larger difference between ethanol and corn prices) before investing in a NGC. Agents in a perfectly competitive market will be willing to invest in the least favorable states. This is because bid shading in a discriminatory auction creates a thin market and, hence, the investment is less reversible than the other types of NGC. A perfectly competitive market has the most liquid stock market and, hence, investment is the most reversible.

Individual agent investment decisions have a direct impact on the firms' ability to form and survive. Since investment in a NGC with a perfectly competitive market is the most reversible, this type of NGC will be able to raise the necessary capital under conditions where NGC's with other stock market structures could not. Consequently, NGC's with this market structure will have the easiest time forming. At the other extreme, a NGC using a discriminatory auction market will require the most favorable conditions before it will be able to form since illiquidity in the market for its shares makes investment less reversible. However, it is important to note that even a discriminatory auction NGC may be able to form at states where the NGC is unprofitable.

The NGCs' exit thresholds mirror the formation thresholds. Discriminatory auction NGC's will tend to exit the market, either through the sale of its stock or by members abandoning their shares, under the most favorable states. Agents who own shares in a NGC with a perfectly competitive market for its stock will place a higher value on their investment and will exit only under the worst conditions.

As discussed in Chapter 4, a perfectly competitive market for NGC stock may be unattainable due to the restrictions on the type of person who can become a member. For a group trying to organize a NGC, it is clear a competitive auction mechanism, where successful buyers and sellers trade at a common market clearing price, creates the incentives that make the market the most liquid, keep stock prices higher, and make the cooperative easier to form and more stable once it has formed.

The last main objective of this study was to create a model of investment in an ethanol plant by an investor-owned firm and then use that model, as well as the NGC models, to look as two policy questions; takeovers of NGC's by IOF's and the impact of ethanol subsidies.

Takeovers of NGC's are most likely to occur when the ethanol price and the corn price are both low. IOF's care only about profit and are indifferent between high ethanol and corn prices and low ethanol and corn prices so long as the difference between the two is the same. NGC investors, on the other hand, lose some benefit of diversification when the corn price is low and so are more eager to sell in that situation. The result is that takeovers are most likely when the ethanol plant is slightly unprofitable and the corn price is low.

With respect to ethanol subsidies, it was shown that removing the ethanol subsidy would have a greater impact on the IOF than on the NGC investors. The IOF is motivated solely by profit, and removing the subsidy reduces profit. NGC investors, on the other hand, desire both profit and diversification, a benefit that remains intact for NGC producers even when the subsidy is removed. This implies that removing the ethanol subsidy would result in fewer ethanol plants, but those that do form would most likely be NGC's. Existing NGC's would also be less likely to be taken over if the ethanol subsidy were eliminated, although more NGC's would be abandoned by their members.

7.2 FUTURE RESEARCH

Dynamic programming methods similar to those used here could be used for applications that were beyond the scope of this study. An important issue that has been left open is the relative strengths and weaknesses of a traditional cooperative as opposed to the NGC or an IOF. It is generally believed that traditional cooperatives have a difficult time raising capital and are not the best organizational form for costly ventures such as ethanol plants. By incorporating a model of a traditional cooperative into the analysis, it may be possible to explain whether this is the case.

Another way in which this study could be expanded is to examine other stock trading mechanisms. There are scores of other auction mechanisms and non-auction trading methods. For example, a stock trading market in which members are responsible for negotiating with each other could be modeled as a bargaining game along the lines of Harsanyi (1977). This is a common method employed by cooperatives and it is unclear where the investment and exit thresholds would fall for a NGC using this mechanism. A bargaining game model of this sort raises significant computational difficulties, but these do not appear to be insurmountable.

There are many other new generation cooperative issues that might be addressed with this model. For instance, it would be fairly easy to vary the population of producers to see how the entry thresholds change. This sort of analysis might be helpful to cooperative promoters who are trying to choose a location for an ethanol plant. It may also be useful to make the plant size an endogenous variable in the model. While NGC's in Minnesota typically choose to build a small plant to maximize the impact of the ethanol subsidy, IOF's, which dominate the ethanol industries of other states, typically choose to build larger plants in order to take advantage of economies of scale. Allowing the organization to choose the plant size may explain why IOF's are more common in the ethanol industry outside of Minnesota.

Finally, dynamic programming methods might be used to analyze internal NGC governance issues. In this model the patronage refund was assumed to be equal to the total amount of the cooperative's profit. In reality, cooperative managers choose a percentage of the profit to return to members. This decision is often influenced not only by the cooperative's need for capital but also by the need to appease members so that they do not leave the cooperative. This model, or one like it, could be modified to analyze the effect of changing the size of the patronage refund. Other management decisions, such as the corn price paid to members, could be analyzed in the same manner.

APPENDIX A

Ethanol and Corn Price Data

Year	CPI (2000 = 100), All urban Consumers, U.S. City Average, All Items	Nominal Corn Price (MN Marketing year average price, $/bu.)	Real Corn Price (2000 $'s)	Nominal Ethanol Price (MN annual average, $/gal)	Real Ethanol Price (2000 $'s)	Adjusted, Real Ethanol Prices (2.45 gal./bu.)
2000	100.00	1.75	1.75	1.43	1.43	3.50
1999	96.75	1.60	1.65	1.00	1.03	2.53
1998	94.66	1.71	1.81	1.11	1.17	2.87
1997	93.21	2.15	2.31	1.24	1.33	3.26
1996	91.11	2.47	2.71	1.48	1.62	3.98
1995	88.50	3.14	3.55	1.18	1.33	3.27
1994	86.06	2.23	2.59	1.29	1.50	3.67
1993	83.91	2.26	2.69	1.24	1.48	3.62
1992	81.48	1.91	2.34	1.37	1.68	4.12
1991	79.09	2.22	2.81	1.25	1.58	3.87
1990	75.90	2.17	2.86	1.33	1.75	4.29
1989	72.01	2.27	3.15	1.22	1.69	4.15
1988	68.70	2.40	3.49	1.20	1.75	4.28
	***Source**: U.S. Dept. of Labor, Bureau of Labor Statistics*	***Source**: Minnesota Agricultural Statistics (various years)*		***Source**:Ye, "Economic Impact of the Ethanol Industry in Minnesota (2002)*		

APPENDIX B

Structure of Matlab code for a typical agent problem

CoopInvest

1. Calls Parameters through "**coopparam**"
2. Sets up output
3. Creates normally distributed error terms based on parameters and using "**splibas**" and "**nodeunif**" functions. Then creates the "s" matrix (the possible values for each state) using these errors.
4. Calculates value functions
   a. Solves for terminal value by selling all shares and calculating the resulting value – also calculates the first coefficient "*c*" for the terminal value function
   b. Solves Bellman equation from T-1 to 1 using "**vmaxh1**" function and inputs "s, c and t"
   c. Will get "***vf***", which is the optimal value for every possible state
5. Calculates (using "***phi***" and "***vf***") and stores the coefficients of the value function in "***copf***" matrix
6. Calculates change in x (control variable) from one period to the next to check for convergence
7. Clears variables

CoopParam

1. Gives parameters of variables
2. Identifies which functions will be used

Splibas and nodeunif

Linear Spline basis functions and nodes

Vmaxh1

1. Finds the bounds of the control variables using "**bound**"
2. Finds the optimal v (value) and x (control) at each node (takes the output from "**vxcoop**" and identifies the maximum v and x.
3. In the auction setting this file also calls "**normalprobtrade**" to determine the probability of buying and selling

Vxcoop

Calculates v as a function of x at each node (i.e. it loops through the q=11 possible controls and calculates the value function at each node) by evaluating "**valuefc**" at each possible control "***x***"

Gstatec

1. Calculates a matrix "***g***" of all possible values of the three state variables using the error matrix "***ek***"

Valuefce

1. This is where the formula for the value function is contained.
2. It determines all possible states by evaluating "**gstatec**" at all possible states and getting vector "***g***"
3. It then gets a scalar value ("***vval***") which is the terminal value by taking "***c***" from "**coopinvest**"
4. Then calculate current period profit
5. Then find the expectation of the value by applying "***w***", a vector of probabilities
6. The result is the expected value of the Bellman equation, "***v***".
7. In "**Coopinvest**", this will be looped from T-1 to period 1

ValuefCE.m
(calculates the value function for agents in NGC's achieving a competitive market for its shares)

```
function v = valuefCE(s,c,t,x)

% value function for one control, 4 number of states
% s is set of all states
% x is (nn by 1), c is (nn by 1), s is (nn by 4), t is scalar

global basis n sminv smaxv smin smax e w T rp rn tcs tcb fme fds fdb si ...
   gamma0 alpha0 Ccost land Pcost lambda theta dist gstate
v = zeros(size(s,1),1);
vval = zeros(size(s,1),1);
TWval = zeros(size(s,1),1);
K = size(e,1);
for k = 1:K
   wk = w(k);
   ek = e(k,:);
   g = feval(gstate,s,x,ek);
   D = size(g,2);
   phi = cell(1,D);
   for d=1:D
      if basis=='splibas'
        phi{d} = feval(basis,n(d),smin(d),smax(d),g(:,d),0,1);
             else
        phi{d} = feval(basis,n(d),smin(d),smax(d),g(:,d));
      end
   end
   vval = cdprodx(phi,c);    % Value of resulting state.
   vval = vval/(1+rp);

   % We also need to calculate the expected profit for each
   % combination of current state and control. We add these
   % two expectations together to get the expected value of the
   % Bellman equation.

   yield = gamma0 + ek(3);

   if (yield*land/2 - g(:,3))<0
      ncrev = (1+tcb).*g(:,1).*(yield*land - g(:,3)) - Ccost*land;
   else
      ncrev = g(:,1).*(yield*land - g(:,3)) - Ccost*land;
   end
   crev = g(:,3).*(g(:,1)+ tcs + (g(:,4) - g(:,1) - Pcost)) - (s(:,2).*x);

   if lambda==0
      vval = vval + ncrev + crev;
   else
      vval = vval - exp(-lambda*(ncrev + crev));
   end
   v = v + vval.*wk;
end
```

Valuefauct.m
(calculates the value function for agents in NGC's using a discriminatory auction trading mechanism)*

```
function v = valuefauct(s,c,t,x,spi)

% value function for one control, 4 number of states, when there is some probability of
% not being able to execute a trade
% s is set of all states
% x is (nn by 1), c is (nn by 1), s is (nn by 4), t is scalar

global basis n sminv smaxv smin smax e w T rp rn tcs tcb fme fds fdb si ...
   gamma0 alpha0 Ccost land Pcost lambda theta dist gstate PP Shrange

if nargin ==4
   spi = zeros(size(s,1),1);
end

v = zeros(size(s,1),1);
vval = zeros(size(s,1),1);
TWval = zeros(size(s,1),1);
K = size(e,1);
esp = expshpr(s,spi);         % calculates an nn by 1 vector of expected share prices
                              % (E[SP] given state and reserve price)

for k = 1:K
   wk = w(k);
   ek = e(k,:);
   g = feval(gstate,s,x,ek);
   D = size(g,2);
   phi = cell(1,D);
   for d=1:D
      if basis=='splibas'
         phi{d} = feval(basis,n(d),smin(d),smax(d),g(:,d),0,1);
      else
         phi{d} = feval(basis,n(d),smin(d),smax(d),g(:,d));
      end
   end
   vval = cdprodx(phi,c);   % Value of resulting state.
   vval = vval/(1+rp);

   % We also need to calculate the expected profit for each
   % combination of current state and control. We add these
   % two expectations together to get the expected value of the
   % Bellman equation.

   yield = gamma0 + ek(3);

   if (yield*land/2 - g(:,3))<0
      ncrev = (1+tcb).*g(:,1).*(yield*land - g(:,2)) - Ccost*land;
   else
```

* The value function m-file for the competitive auction market is very similar and is not reproduced here

```
    ncrev = g(:,1).*(yield*land - g(:,2)) - Ccost*land;
  end

    %if x is positive, the agent is a buyer and the price paid is the price bid

  if x>=0
    crev = g(:,2).*(g(:,1)+ tcs + (g(:,3) - g(:,1) - Pcost)) - (spi.*x);

    % if x is negative, the agent is a seller and the price received is an expectation
    % which is a function of the reserve price and the states

  else
    crev = g(:,2).*(g(:,1)+ tcs + (g(:,3) - g(:,1) - Pcost))- (esp.*x);
      %crev = g(:,2).*(g(:,1)+ tcs + (g(:,3) - g(:,1) - Pcost))- (spi.*x);
  end

  if lambda==0
    vval = vval + ncrev + crev;
  else
    vval = vval - exp(-lambda*(ncrev + crev));
  end
  v = v + vval.*wk;              % v is a nn by 1 vector

end            % end state loop
```

Normalprobtrade.m

(creates the functions that define the probability of buying and selling shares in the auction markets)

```
function [prbuy, prsell] = Normalprobtrade(s);

global  BuyParam SellParam q Shrange prsell prbuy PSsize AskVar BidVar

PP=size(Shrange,2);
nn=size(s,1);

ShRep=repmat(Shrange,nn,1);          % ShPrRep is nn by PP
CPRep=repmat(s(:,1),1,PP);           % CPRep is nn by PP
EPRep=repmat(s(:,3),1,PP);           % CPRep is nn by PP

                 % use s instead of g here because trades are made before the
                 % present period's prices are known

% PROBABILITY OF BUYING
% creates density of low reserve price based on parameters then makes cumulative function
% i.e. the probability that the low reserve price will be below a given bid

expask = SellParam(1) + SellParam(3).*EPRep + SellParam(4).*CPRep;  % exp.low reserve(nn by PP)
askrange = ShRep - expask;           % make it mean 0
askz = askrange./(AskVar^0.5);       % creates "z" for ask distribution (nn by PP)
asknorm = (1/(2*pi)^0.5)*exp(-((askz.^2)/2));    % standard normal distribution for residuals (nn by
PP)
asksum = sum(asknorm,2);             % (nn by 1)
zeroa = find(asksum==0);
anotz = find(asksum~=0);
for i=1:PP
  asknorm(anotz,i) = asknorm(anotz,i)./asksum(anotz);   % rescale so intergrates to 1 (prob. density
function)
  asknorm(zeroa,i) = 0;              % no probability of trading in relevant price range
end
lowpr = find(asknorm<0.01);
asknorm(lowpr)=0;
askcum = zeros(nn,PP);
askcum(:,1) = asknorm(:,1);
for i=2:PP
  askcum(:,i)= asknorm(:,i)+askcum(:,i-1);   % nn by PP matrix of cumulative probabilities
end
prbuy=zeros(q,nn,PP);
for i=1:q
  prbuy(i,:,:) = askcum;             %prbuy is now q by nn by PP
end

%PROBABILITY OF SELLING
expbid = BuyParam(1) + BuyParam(3).*EPRep + BuyParam(4).*CPRep;  % exp.high bid(nn by PP)
bidrange = ShRep - expbid;           % make it mean 0
bidz = bidrange./(BidVar^0.5);       % creates "z" for ask distribution (nn by PP)
bidnorm = (1/(2*pi)^0.5)*exp(-((bidz.^2)/2));    % standard normal distribution for residuals (nn by
PP)
bidsum = sum(bidnorm,2);             % (nn by 1)
```

```
zerob = find(bidsum==0);
bnotz = find(bidsum~=0);
for i=1:PP
   bidnorm(bnotz,i) = bidnorm(bnotz,i)./bidsum(bnotz);    % rescale so intergrates to 1 (prob. density
function)
   bidnorm(zerob,i) = 0;                  % no probability of trading in relevant price range
end
lowpr = find(bidnorm<0.01);
bidnorm(lowpr)=0;
bidcum = zeros(nn,PP);
bidcum(:,PP) = bidnorm(:,PP);
for i=1:PP-1
   bidcum(:,PP-i)= bidnorm(:,PP-i) + bidcum(:,PP-i+1);   % nn by PP matrix of cumulative
probabilities
end
prsell=zeros(q,nn,PP);
for i=1:q
   prsell(i,:,:) = bidcum;                %prsell is now q by nn by PP
end
```

APPENDIX C

The NGC stock market simulations were performed using Matlab. The competitive market simulation was done by the m-file "compmktsim" and the auction market simulations were done by the m-file "auctionsim." Both of these m-files are included in this appendix. M-files that perform the market clearing functions in the competitive market are also included. The complete set of relevant Matlab code is on file in the Waite Library at the University of Minnesota's Department of Applied Economics.

The general structure of the market simulations is as follows:

<u>If the cooperative has not formed:</u>

- Determine the ethanol price and corn price for the current year from the "prices" file, which was created by generating a set of random prices consistent with the price dynamics discussed in Chapter 2.
- Determine demand for NGC shares by each agent at the initial share price.
- If total demand by all agents exceed the number of shares offered by the NGC, then the cooperative forms.
- If total demand does not exceed the number of shares offered by the NGC, then the cooperative does not form.

<u>If the cooperative has formed:</u>

- Determine the ethanol and corn prices.
- *If the market is competitive*: Check demand for NGC shares for every agent (members and non-members) over the full range of share prices.
- *If the market has an auction mechanism*: Find the optimal bid price and quantity for every agent.
- Clear the market:
  → *In the competitive market*: Find the share price such that total supply is equal to total demand.
  → *In the auction markets*: Find the "stop-out" price and determine successful buyers and sellers.
- Transfer shares accordingly.

<u>After markets clear:</u>

- Update all agent share balances.
- Update ethanol, corn and share prices.
- Proceed to the next year or to the scenario if the previous year = 10.

Compmktsim.m
(simulates trading in a competitive market setting)

```
% This program simulates market behavior for multiple agents who
% follow optimal policies determined by dynamic programming.

clear all;

global bound asmin asmax lotsize valuef e w T Inter EPCoeff CPCoeff SPCoeff...
   gamma0 alpha0 Ccost aland Pcost alambda atcs atcb ns mkttype

mkttype = 'competitive';
% Create array of file names and define cooperative parameters
agentpopulation2;
% Load the model parameters and optimal value functions for all agents

na = size(anames,1);   % Number of agents
ns = 25;               % Number of scenarios
ny = 10;               % Number of years simulated
minsp = 0;             % Minimum share price
maxsp = 8;             % Maximum share price
spstep = 0.1;          % Share price step
nspstep = 1 + (maxsp-minsp)/spstep;
sparray = [minsp:spstep:maxsp];

load Prices;

% Create arrays of agent specific variables.
asmin = cell(1,na);
asmax = cell(1,na);
atcs = zeros(1,na);
aland = zeros(1,na);
alambda = zeros(1,na);
aage = zeros(1,na);
acopt = cell(1,na);
as = zeros(na,4);
ax = zeros(na,nspstep);

% Create arrays of market variables to be saved.
SPrice = zeros(ns,ny);    % Equilibrium Share Prices
CPrice = zeros(ns,ny);    % Equilibriun Corn Prices
EPrice = zeros(ns,ny);    % Equilibriun Ethanol Prices
MVolume = zeros(ns,ny);   % Market Volumes
endbal = zeros(na,ns);    % Balances in final year

% Create arrays of agent-specific variables to be saved
AAPurchase = zeros(ns,ny,na);  % Actual Purchases
AADemand = zeros(ns,ny,na);    % Actual Demand at Equilibrium Price


% Read output files for the agents.
for k = 1:na
   load(anames(k,:));
   asmin{k} = smin;
   asmax{k} = smax;
```

```
   atcs(k) = tcs;
   atcb(k) = tcb;
   aland(k) = land;
   alambda(k) = lambda;
   acopt{k} = copt;
end
%lotsize = 5000                    % only use if want a different size than in agent files
% Specify age for each agent
aage = ones(1,na);                 % for infinite horizon use year 1 for all agents

% Define relevant m-files
vmaxh = 'vmaxh1sim';
bound = 'boundcsim';
valuef = 'valuefcsimvec';
basis = 'splibas';


% Simulate the market for ns scenarios of nature over ny years
for i = 1:ns
   fprintf('State = %2i\n',i)
   % Reinitialize the states for each agent
   SH = zeros(na,1);    % All agents start with no shares.
   %CP = 2;          % Initial corn price.
   %EP = 4;
   CP = StatePr{1}(i,1);
   EP = StatePr{2}(i,1);

   coopexist = 0;     % Binary variable equal to one after coop has formed.
   %coopexist = 1;
   sage=aage;          % Reset ages to initial values.
   as(:,1) = CP;
   as(:,2) = initshp;
   as(:,3) = SH;
   as(:,4) = EP;
   for j = 1:ny
      fprintf('  Year = %2i\n',j)
      % Generate share demand curve over range of share prices
      % for each agent.
      for k = 1:na
         fprintf('    Agent = %2i\n',k)

         same = 0;
         if k>1
            if anames(k,:)==anames(k-1,:)
               if as(k,3)==as(k-1,3)
                  same = 1;
               else
                  same = 0;
               end
            end
         end

         if sage(k)==T
            c = [];
         else
            c = acopt{k};
```

```
      c = c(:,sage(k)+1);
    end    % sage if
    if coopexist == 0
      % Check demand at initial price
      if same ==0
        [ax(k,1),v] = feval(vmaxh,as(k,:),c,sage(k),k);
      elseif same==1
        ax(k,1) = ax(k-1,1);
      end
    else
      % Check demand over a range of prices
      if same==0
        assp = zeros(nspstep,4);
        assp(:,1) = as(k,1);
        assp(:,2) = sparray';
        assp(:,3) = as(k,3);
        assp(:,4) = as(k,4);
        [axsp,v] = feval(vmaxh,assp,c,sage(k),k);
        ax(k,:) = axsp';
      elseif same==1
        ax(k,:) = ax(k-1,:);
      end
    end    % coopexist if
  end    % agent loop
  % Determine market outcomes.
  if coopexist == 0
    SP = initshp
    %ax(:,1)'
    demand = sum(ax(:,1));
    %fprintf('      Total Demand = %10i\n',demand)
    if demand >= coopcap
      nax = zeros(na,1);
      nax = newcoopclear(na,as,ax,demand,coopcap,lotsize);
      for k = 1:na
        AADemand(i,j,k) = ax(k,1);
        AAPurchase(i,j,k) = nax(k);
      end
      ax(:,1) = nax;
      % allocate shares (put actions in ax(,1))
      coopexist = 1;
    else
      ax(:,1) = 0;
      nax = ax(:,1);
    end    % demand if
  else
    spl = 1;   % index for share price level
    nz = 0;    % number of prices with zero excess demand
    %ax';
    demand = sum(ax(:,spl));
    while demand > 0 & spl < nspstep
      spl = spl+1;
      demand = sum(ax(:,spl));
      if demand == 0
        nz = nz+1;
      end
    end
```

```
        nax = zeros(na,1);
        [nax,nsp] = oldcoopclear(na,as,ax,demand,coopcap,lotsize,sparray,SP,spl,nz);
        for k = 1:na
          AADemand(i,j,k) = ax(k,nsp);
          AAPurchase(i,j,k) = nax(k);
        end
        ax(:,1) = nax;
        ax(:,1)'
        SP = sparray(nsp)
        % Determine market clearing price and allocate shares (put actions in ax(,1))
        % Also update the share price for all agents.
      end    % coopexist if
      SPrice(i,j) = SP;
      CPrice(i,j) = CP;
      EPrice(i,j) = EP;
      pax = max(0,ax(:,1));
      MVolume(i,j) = sum(pax);
      fprintf('        Volume = %10i\n',sum(pax))


      % Update holdings for each agent.
      for k = 1:na
        as(k,3) = as(k,3)+ax(k,1);
      end

      % Update corn price.

      %CP = CP.*exp(cerror(i,j));                        % Corn price state eqn
      %CP = max(smin(1),min(CP,smax(1)))
      if j<10
        CP = StatePr{1}(i,j+1)
      end
      as(:,1) = CP;
      % Update ethanol price.
      %EP = EP.*exp(eerror(i,j));           % Ethanol price state eqn
      %EP = max(smin(4),min(EP,smax(4)))
      if j<10
        EP = StatePr{2}(i,j+1)
      end
      as(:,4) = EP;
      % Update the share price
      as(:,2) = SP;
    end    % year loop
    endbal(:,i) = as(:,3);
  end        % scenario loop

save [flname] ns ny na endbal SPrice EPrice CPrice MVolume AADemand AAPurchase;

% Save results and quit.
```

Newcoopclear.m
(clears the market for NGC shares at the formation stage)

```
function nax = newcoopclear(na,as,ax,demand,coopcap,lotsize);
% This function allocates shares among agents at coop formation time.
% na       number of agents
% as       na x 3 array of cuurent states ... CP, SP, Shares
% ax       na vector of desired share purchases
% coopcap  maximum number of coop shares
% lotsize  minimum number of shares purchased ... purchases are multiples of this
% nax      na vector of actual purchases

% This was written in early August by Steve and Rob.

if demand == coopcap
   nax = ax(:,1);
else
   shleft = coopcap;
   sam = zeros(na,1);
   nax = zeros(na,1);
   while shleft > 0
      %generate discrete uniform rv between 1 and na
      urv = min(na,round((na*rand)+0.5));
      if sam(urv,1) == 0
         sam(urv,1) = 1;
         nax(urv,1) = min(ax(urv,1),shleft);
         shleft = shleft - nax(urv,1);
      end
   end
end
```

Oldcoopclear.m
(clears the market for NGC shares after formation has occurred)

```
function [nax,nsp] = oldcoopclear(na,as,ax,demand,coopcap,lotsize,sparray,SP,n,nz);
% This function allocates shares among agents at coop formation time.
% na       number of agents
% as       na x 3 array of cuurent states ... CP, SP, Shares
% ax       na x 1 vector of desired share purchases
% coopcap  maximum number of coop shares
% lotsize  minimum number of shares purchased ... purchases are multiples of this
% SP       most recent share price
% n        last share price index before calling
% nz       number of zero demand before calling
% nax      na x 1 vector of actual purchases
% nsp      scalar index of new share price

% This was written in early August by Steve and Rob.

if demand == 0
   if nz == 1
      nax = ax(:,n);
      nsp = n;
   else
      nnz = nz - 1
      minspdif = abs(sparray(n) - SP);
      nsp = n;
      for nn=1:nnz
         spdif = abs(sparray(n-nn) - SP);
         if spdif < minspdif
            minspdif = spdif;
            nsp = n - nn;
         end
      end
      nax = ax(:,nsp);
   end
elseif demand < 0  %  We go to lowest price
   nsp = n;
   nax = zeros(na,1);
   pax = max(ax(:,n),0);
   pdemand = sum(pax);
   shleft = pdemand;
   sam = zeros(na,1);
   % We can make this more efficient later
   for nn=1:na
      if ax(nn,n) > 0
         nax(nn,1) = ax(nn,n);
         sam(nn,1) = 1;
      end
   end
   while shleft > 0 % & sum(sam(:,1)) < na
      %generate discrete uniform rv between 1 and na
      urv = min(na,round((na*rand)+0.5));
      if sam(urv,1) == 0
         sam(urv,1) = 1;
         nax(urv,1) = -min(-ax(urv,n),shleft);
```

```
            shleft = shleft + nax(urv,1);
         end
      end
   else  % We have excess demand and go to highest price
      nsp = n;
      nax = zeros(na,1);
      pax = min(ax(:,n),0);
      %psupply = -sum(pax(:,n));
      psupply = -sum(pax);
      shleft = psupply;
      sam = zeros(na,1);
      % We can make this more efficient later
      for nn=1:na
         if ax(nn,n) < 0
            nax(nn,1) = ax(nn,n);
            sam(nn,1) = 1;
         end
      end
      while shleft > 0 % & sum(sam(:,1)) < na
         %generate discrete uniform rv between 1 and na
         urv = min(na,round((na*rand)+0.5));
         if sam(urv,1) == 0
            sam(urv,1) = 1;
            nax(urv,1) = min(ax(urv,n),shleft);
            shleft = shleft - nax(urv,1);
         end
      end
   end
```

Auctionsim.m
(simulates trading in a discriminatory or competitive auction setting)

```
% This program simulates a closed-bid, first-price, multi-unit, discriminatory auction
% for multiple agents who follow optimal bidding determined by dynamic programming.

clear all;

global bound asmin asmax lotsize valuef e w T Inter EPCoeff CPCoeff SPCoeff...
   gamma0 alpha0 Ccost aland Pcost alambda atcs atcb ns vxcoop sparray initshp mkttype

% Create array of file names
mkttype = 'auction';
agentpopulation;

% Define cooperative parameters
lotsize = 1000;    % Share transaction are multiples of this.

% Load the model parameters and optimal value functions for all agents

na = size(anames,1);   % Number of agents
ns = 10;               % Number of scenarios
ny = 10;               % Number of years simulated
minsp = 0;             % Minimum share price
maxsp = 8;             % Maximum share price
spstep = 0.10;         % Share price step
nspstep = 1 + (maxsp-minsp)/spstep;
sparray = [minsp:spstep:maxsp];

load Prices2;

% Create arrays of agent specific variables.
asmin = cell(1,na);
asmax = cell(1,na);
atcs = zeros(1,na);
aland = zeros(1,na);
alambda = zeros(1,na);
aage = zeros(1,na);
acopt = cell(1,na);
as = zeros(na,3);
ax = zeros(na,1);
ap = zeros(na,1);
optpol = cell(1,ns);

demsch = zeros(na,size(sparray,2));

% Create arrays of market variables to be saved.
SOPrice = zeros(ns,ny);        % Stop-out Prices
BidPrice = zeros(ns,ny,na);    % Bids
AskPrice = zeros(ns,ny,na);    % Asks
SpTrades = zeros(ns,ny,na);    % Quantities of specific purchases
CPrice = zeros(ns,ny);         % Corn Prices
EPrice = zeros(ns,ny);         % Ethanol Prices
MVolume = zeros(ns,ny);        % Market Volumes
```

```
% Create arrays of agent-specific variables to be saved
AATrade = zeros(ns,ny,na);     % Actual Trades
%AADemand = zeros(ns,ny,na);   % Actual Demand at Equilibrium Price


% Read output files for the agents.
for k = 1:na
   load(anames(k,:));
   asmin{k} = smin;
   asmax{k} = smax;
   atcs(k) = tcs;
   atcb(k) = tcb;
   aland(k) = land;
   alambda(k) = lambda;
   acopt{k} = copt;
end
% Specify age for each agent
aage = ones(1,na);              % for infinite horizon use year 1 for all agents

% Define relevant m-files

bound = 'boundauctsim';
valuef = 'valuefauctsim';
basis = 'splibas';

% Simulate the market for ns scenarios of nature over ny years
for i = 1:ns
   fprintf('State = %2i\n',i)
   % Reinitialize the states for each agent

   SH = zeros(na,1);    % All agents start with no shares.
   CP = StatePr{1}(i,1);
   EP = StatePr{2}(i,1);
   coopexist = 0;     % Binary variable equal to one after coop has formed.
   %coopexist = 1;
   sage=aage;        % Reset ages to initial values.
   as(:,1) = CP;
   as(:,2) = SH;
   as(:,3) = EP;
   optpol{i}=zeros(na,2,ny);

   for j = 1:ny
      fprintf('  Year = %2i\n',j)
      % Generate share demand curve over range of share prices
      % for each agent.
      for k = 1:na
         fprintf('    Agent = %2i\n',k)

         same = 0;
         if k>1
            if anames(k,:)==anames(k-1,:)
               if as(k,2)==as(k-1,2)
                  same = 1;
               else
                  same = 0;
               end
```

```
      end
    end
    c = acopt{k};
    c = c(:,sage(k)+1);

% Here we find optimal bidding strategies

    % When the coop does not exist the only decision to be made is the quantity.
    % This model finds initial "demand" by determining the optimal quantity that would
    % be "bid", give the initial share price.
    % By using the auction model to determine demand, I am implicitly assuming the agent expects
    % the coop to form regardless of how much he chooses to buy.

      if coopexist == 0
        % redefine the functions for no coop
        vmaxh = 'vmaxaucnewcoop';
        vxcoop = 'vxcoopaucnewcoop';

        % define the states as the initial prices and SH = 0
        initst = zeros(1,3);
        initst(1) = CP;          % corn price
        initst(2) = as(k,2);      % share balance (zero in this case)
        initst(3) = EP;          % ethanol price

        % Check demand at initial price
        if same ==0
          [ax(k),v] = feval(vmaxh,initst,c,sage(k),k);
          ap(k) = initshp;
        elseif same==1
          ax(k) = ax(k-1);
          ap(k) = ap(k-1);
        end
      else              % cooperative has already formed
        % set correct file paths
        vmaxh = 'vmaxauctsim';
        vxcoop = 'vxcoopauctsim';

        % Find optimal price / quantity combination
        if same==0
          assp = zeros(1,3);
          assp(:,1) = as(k,1);       % Corn Price
          assp(:,2) = as(k,2);      % Share balance
          assp(:,3) = as(k,3);      % Ethanol Price
          [axsp,v,apsp] = feval(vmaxh,assp,c,sage(k),k);
          ax(k) = axsp;                      % returns optimal quantity bid
          ap(k) = apsp;                      % returns optimal price bid
          if axsp <0
            xsort = sparray >= apsp;      % Sellers (ones for SP's higher than the reserve-
          else                  %         zeros otherwise)
            xsort = sparray <= apsp;      % Buyers (ones for SP's lower than the bid-
          end                   %         zeros otherwise
          demsch(k,:) = xsort.*ax(k);   % makes demand = axsp for favorable prices, zero otherwise
         elseif same==1
          demsch(k,:) = demsch(k-1,:);
          ap(k) = ap(k-1);
          ax(k) = ax(k-1);
```

```
            end

        end    % coopexist if
     end    % agent loop

% Determine market outcomes.

     % initial formation
     if coopexist == 0
        SP = initshp
        %ax(:,1)'
        demand = sum(ax(:,1));
        fprintf('        Total Demand = %10i\n',demand)
        if demand >= coopcap
           nax = zeros(na,1);
           nax = newcoopclearauct(na,ax,demand,coopcap,lotsize)
           for k = 1:na
              %AADemand(i,j,k) = ax(k,1);
              AATrade(i,j,k) = nax(k);
           end
           ax(:,1) = nax;
           % allocate shares (put actions in ax(,1))
           coopexist = 1;
        else
           ax(:,1) = 0
           SOP = initshp;
        end    % demand if
        bids = SP;
        asks = 0;
        shexch = ax(:,1);
        SOP = initshp;

      % cooperative has already formed

      %  CLEARING THE MARKET:

      % net demand at each share price is sum of ax(:,[])
      % want to find the price (the column of ax) where net demand is closest to zero
      % the price corresponding to this column is the stop-out price
      % all bids above the stop-out price are successful
      % all reserves below the stop-out price are successful
      % then match up successful bids and asks (done in 'oldcoopclearauct')
           % buyers pay their bid price
           % sellers matched up with successful bidders randomly


     else
        buyagind = demsch>0;
        sellagind = demsch<0;
        buyag = buyagind.*demsch;
        sellag = sellagind.*demsch;
        demand = sum(buyag);
        demandind = demand>0;
        supply = sum(sellag);
        supplyind = supply<0;
        aggdemind = demandind+supplyind;
```

```
  spindtemp = find(aggdemind==2);
  if isempty(spindtemp)               % no prices where supply and demand exist
    excessd = demand - supply;
    [mktcldem, spind] = min(abs(excessd)); % find the price where S is close to D
    %[mktcldem2, spind3]=min(abs(fliplr(excessd)));
    %spind = round((spind2+(length(sparray)+1-spind3))/2);
  else                        % supply and demand both exist
    [mktcldem, spind2] = min(abs(demand(spindtemp)-supply(spindtemp)));
    spind = spindtemp(spind2);     % find price where S closest to D
  end

  Aggdemand = sum(demsch(:,spind));


  % identify quantities to be traded, who are buyers and who are sellers

  tradex = demsch(:,spind);         % tradex is (na by 1)
  buyers = tradex>0;
  sellers = tradex<0;
  asks = sellers.*ap;
  bids = buyers.*ap;

  [shexch] = oldcoopclearauct(demsch,ap,na,Aggdemand,spind,buyers,sellers,tradex);

  for k = 1:na
    AATrade(i,j,k) = shexch(k);       % tells how many shares each agent trades
  end
  SOP = sparray(spind)        % identifies stop-out price
end        % ends if coopexists, else cycle -- market outcomes are determined

% Record market outcomes

SOPrice(i,j) = SOP;       % stop-out price
CPrice(i,j) = CP;         % corn price
EPrice(i,j) = EP;         % ethanol price
pax = max(0,shexch);
MVolume(i,j) = sum(pax);   % trading volume
VOL = MVolume(i,j)
optpol{i}(:,1,j) = ax;     % optpol gives optimal quantities and prices for each
optpol{i}(:,2,j) = ap;         % agent, for each year, and for each scenario
%SpTrades(i,j,:) = pax;

% Update holdings for each agent.
for k = 1:na
  as(k,2) = as(k,2) + shexch(k);

end

% Update corn price.
%CP = CP.*exp(cerror(i,j));                  % Corn price state eqn
%CP = max(smin(1),min(CP,smax(1)))
if j<10
  CP = StatePr{1}(i,j+1)
end
as(:,1) = CP;
% Update ethanol price.
```

```
    %EP = EP.*exp(eerror(i,j));            % Ethanol price state eqn
    %EP = max(smin(3),min(EP,smax(3)))
    if j<10
      EP = StatePr{2}(i,j+1)
    end
    as(:,3) = EP;
  end    % year loop

end       % scenario loop

% Save results and quit.
save [flname] ns ny na as SOPrice optpol AATrade Epric
```

APPENDIX D

Two of the most important aspects of this study are to determine the formation thresholds and exit thresholds for different NGC's. The formation thresholds in the competitive market were performed by the m-file "ceformthresh," and the exit thresholds were calculated by "exitthreshold." Both of these m-files are included in this appendix. The comparable files for the auction markets and the supporting m-files are on file in the Waite Library at the University of Minnesota's Department of Applied Economics.

The procedure for finding formation thresholds is as follows:

- Prior to the cooperative's formation the initial share price was $3.75 and the initial share balance for all agents is 0.
- Given this share price and share balance, calculate the demand for NGC shares for every agent in the population at every possible ethanol price / corn price combination.
- At each state, determine if total demand exceeds the number of shares offered. If so, then conclude the NGC would form.
- All states at which the cooperative would form are included in the formation region while the states at which the cooperative will not form are included in the region of no formation.
- The formation threshold is the set of states that separates these two regions.

The procedure for finding exit thresholds is as follows:

- Determine a the distribution of agent types and share balances for a "typical" NGC membership based upon the market simulations (see Appendix 4.1).
- For every possible ethanol price / corn price combination calculate the demand for NGC by every member and at every possible share price.
- At each share price, determine how many votes would be cast to sell the NGC (i.e. calculate how many members want to sell all of their shares) under both member voting and share voting rules.
- Find the lowest share price at which enough votes would be cast to sell all share of the NGC to satisfy each of the four voting rules.
- Continue this process for each ethanol price / corn price combination.

Ceformthresh.m
(finds the share price at which agents will form a NGC at all possible states)

```
% This program checks for cooperative formation over a range of corn and ethanol prices

clear all;

global bound asmin asmax lotsize valuef e w T Inter EPCoeff CPCoeff SPCoeff...
   gamma0 alpha0 Ccost aland Pcost alambda atcs atcb ns mkttype

mkttype = 'competitive';
% Create array of file names and define cooperative parameters
agentpopulationPA;
anames = panames;
% Load the model parameters and optimal value functions for all agents
ShPr = [3.75];
PEr = [2.00:0.10:5.00];
PCr = [1.00:0.10:4.00];
[PE PC] = meshgrid(PEr,PCr);
EPent = cell(1,length(ShPr));
CPent = cell(1,length(ShPr));
demand = cell(1,length(ShPr));
SPent = zeros(size(PE));
SPent(:,:) = ShPr(1);

na = size(anames,1);    % Number of agents

% Create arrays of agent specific variables.
asmin = cell(1,na);
asmax = cell(1,na);
atcs = zeros(1,na);
aland = zeros(1,na);
alambda = zeros(1,na);
aage = zeros(1,na);
acopt = cell(1,na);

%as = zeros(length(PCr),4);
as = zeros(1,4);
%ax = zeros(length(PCr),length(PEr),na);
ax = zeros(1,na);

% Read output files for the agents.
for k = 1:na
   load(anames(k,:));
   asmin{k} = smin;
   asmax{k} = smax;
   atcs(k) = tcs;
   atcb(k) = tcb;
   aland(k) = land;
   alambda(k) = lambda;
   acopt{k} = copt;
end

% Specify age for each agent
aage = ones(1,na);             % for infinite horizon use year 1 for all agents
```

```
% Define relevant m-files
vmaxh = 'vmaxh1sim';
bound = 'boundcsim';
valuef = 'valuefcsimvec';
basis = 'splibas';

coopexist = 0;     % Binary variable equal to one after coop has formed.
sage=aage;         % Reset ages to initial values.

% search for formation from most profitable to least profitable states

for p=1:length(ShPr)
  fprintf('   Share Price = %2i\n',ShPr(p))
  form = zeros(size(PC,1),size(PE,2));
  for j = 1:size(PC,1)              % check CP's from lowest to highest
    fprintf('   PC = %2i\n',PC(j,1))
    if j>1
      if form(j-1,size(PE,2)) == 0
        break                       % if the highest EP of the last CP considered did not
      end                           % result in the coop formation -- then skip to next SP
    end
    for i = size(PE,2):-1:1         % check EP's from highest to lowest
      % define the state
      as(1) = PC(j,i);
      as(2) = ShPr(p);
      as(3) = 0;
      as(4) = PE(j,i);
      fprintf('         PE = %2i\n',as(4))

        % Check demand at initial price for each agent
      for k = 1:na
        %fprintf('   Agent = %2i\n',k)
        same = 0;
        if k>1
          if anames(k,:)==anames(k-1,:)
            same = 1;
          end
        end
       if same==0;
          c = acopt{k};
          c = c(:,sage(k)+1);
          [ax(k),v] = feval(vmaxh,as,c,sage(k),k);
        else
          ax(k)=ax(k-1);
        end
      end
      demand{p} = sum(ax);
      if demand{p} >=coopcap
        form(j,i)=1;
        %fprintf('      Formation')
      else
        %fprintf('      No Formation')
        break
      end
    end
```

```
    end

    iind = zeros(size(form,1),2);

    for k=1:size(form,1)
        tind = find(form(k,:)==1);
        if isempty(tind)==1
            iind(k,1)=0;
            iind(k,2)=0;
        else
            iind(k,1) = k;
            iind(k,2) = tind(1);
        end
    end
    [zr, zc] = find(iind==0);
    iind(zr,:)=[];
    for i=1:size(iind,1)
        EPent{p}(i) = PE(iind(i,1),iind(i,2));
        CPent{p}(i) = PC(iind(i,1),iind(i,2));
        SPent(i,iind(i,2):size(SPent,2)) = ShPr(p);
    end
end
fprintf('For Results Run: "PlotCEThresh"')
save [flname] PE PC demand EPent CPent SP
```

Exitthreshold.m
(finds the share price at which a NGC will agree to a takeover by an IOF)

```
% finds the share price at which a cooperative will agree to a takeover
% each state has four takeover prices:
%   majority and supermajority of shares
%   majority and supermajority of members

clear all;

global bound asmin asmax lotsize valuef e w T Inter EPCoeff CPCoeff SPCoeff...
   gamma0 alpha0 Ccost aland Pcost alambda atcs atcb ns mkttype

apop = ['SNHRAc'; 'SNSRAc'; 'SFHRAc'; 'SFSRAc'; 'MNHRAc'; 'MNSRAc'; 'MFHRAc'; 'MFSRAc';
'LNHRAc'; 'LNSRAc'; 'LFHRAc'; 'LFSRAc'];
SH = [5000 5000 8000 12000 7000 9000 14000 10000 16000 23000 5000 16000];

% Load the model parameters and optimal value functions for all agents
PEr = [2.00:0.10:5.00];
PCr = [1.00:0.10:4.00];
ShPr = [0:.1:8]';
[PE PC] = meshgrid(PEr,PCr);

na = size(apop,1);    % Number of agents

SHsimplemaj = sum(SH)/2;
SHsupermaj = 2*sum(SH)/3;
Msimplemaj = size(apop,1)/2;
Msupermaj = 2*size(apop,1)/3;

% Create arrays of agent specific variables.
asmin = cell(1,na);
asmax = cell(1,na);
atcs = zeros(1,na);
aland = zeros(1,na);
alambda = zeros(1,na);
aage = zeros(1,na);
acopt = cell(1,na);

% create storage
as = zeros(length(ShPr),4);
Thresh = zeros(size(PE,1),size(PE,2),4);

% Read output files for the agents.
for k = 1:na
   load(apop(k,:));
   asmin{k} = smin;
   asmax{k} = smax;
   atcs(k) = tcs;
   atcb(k) = tcb;
   aland(k) = land;
   alambda(k) = lambda;
   acopt{k} = copt;
end
```

```
% Specify age for each agent
aage = ones(1,na);              % for infinite horizon use year 1 for all agents

% Define relevant m-files
basis = 'splibas';

coopexist = 1;    % Binary variable equal to one after coop has formed.
sage=aage;        % Reset ages to initial values.

% go state by state to determine the price at which a takeover will occur

  for j = 1:size(PC,1)              % check CP's from lowest to highest
    fprintf('    PC = %2i\n',PC(j,1))
    for i = 1:size(PE,2)            % check EP's from lowest to highest
      voteyes = zeros(length(ShPr),na);

      % define the state
      as(:,1) = PC(j,i);
      as(:,2) = ShPr;
      as(:,3) = 0;
      as(:,4) = PE(j,i);
      fprintf('             PE = %2i\n',PE(j,i))

        % Check demand at initial price for each agent
      for k = 1:na
        as(:,3) = SH(k);
        c = acopt{k};
        c = c(:,sage(k)+1);
        [XP] = vmaxExit(as,c,sage(k),k);

        sellall = find(XP == -SH(k));        % find SP's where it is optimal to sell all shares
        voteyes(sellall,k) = 1;

      end

      shares = repmat(SH,length(ShPr),1);
      sales = shares.*voteyes;
      yesshares = sum(sales,2);             % creates a column vector of shares voting for dissolution at
                                            % each share price
      yesmembers = sum(voteyes,2);          % creates a column vector of the number of members voting
                                            % for dissolution at a given price

      A = find(yesmembers > Msimplemaj);
      B = find(yesmembers > Msupermaj);
      C = find(yesshares > SHsimplemaj);
      D = find(yesshares > SHsupermaj);

      if isempty(A)==0
        Thresh(j,i,1) = ShPr(A(1));
      else
        Thresh(j,i,1) = 10;
      end
      if isempty(B)==0
        Thresh(j,i,2) = ShPr(B(1));
      else
        Thresh(j,i,2) = 10;
```

```
        end
        if isempty(C)==0
          Thresh(j,i,3) = ShPr(C(1));
        else
          Thresh(j,i,3) = 10;
        end
        if isempty(D)==0
          Thresh(j,i,4) = ShPr(D(1));
        else
          Thresh(j,i,4) = 10;
        end
      end
    end

save [flname] Thresh apop SH
```

REFERENCES

Barton, David. (1989). "Principles," Chapter 2 in *Cooperatives in Agriculture*. Ed. David Cobia. Prentice Hall, Engelwood Cliffs, New Jersey.

Cason, Timothy. (1993). Seller Incentive Properties of EPA's Emission Trading Auction. J.Environ. Econ. Management, 25, 177-195.

Cook, Michael L. (1995). "The Future of U.S. Agricultural Cooperatives: A Neo-Institutional Approach." *Amer.J.Agr.Econ.* 77: 1153-1159.

Cook, Michael L. (1993). "Cooperatives and Group Action." In *Food and Agricultural Marketing Issues for the 21st Century*. (Daniel I. Padberg, ed.) FAMC 93-1, Texas A&M University, pp.154-69.

Cook, Michael L. and C. Illiopoulis. (1999). "Beginning to Inform the Theory of the Cooperative Firm: Emergence of New Generation Cooperatives." *Finnish Journal of Business Economics* 4:525-35.

Dixit, Avinash K. and Robert S. Pindyck. (1994). *Investment Under Uncertainty.* Princeton University Press, Princeton, New Jersey.

Emelianoff, Ivan V. (1942). *Economic Theory of Cooperation.* Reprinted by Univ. of California, Berkeley Center for Cooperatives, 1995.

Friedman, Daniel. (1991). "A simple testable model of double auction markets." J. Econ. Behavior and Organ. 15, 47-70.

Fruin, Jerry and Konstantinos Rotsios and D. Walter Halbach. (1996). "Minnesota Ethanol Production and It's Transportation Requirements." University of Minnesota, Dept. of Applied Econ. Staff Paper P96-7.

Greene, William H. (2000). *Econometric Analysis.* 4th Ed. Prentice-Hall: Upper Saddle River, New Jersey.

Harris, Andrea and Brenda Stefanson and Murray Fulton. (1996). "New Generation Cooperatives and Cooperative Theory." Journal of Cooperatives, 11:15-28.

Harris, Richard. (1995). *Using Cointegration Analysis in Econometric Modeling.* Prentice-Hall: London.

Harsanyi, John C. (1977). *Rational Behavior and Bargaining Equilibrium in Games and Social Situations.* Cambridge University Press: Cambridge.

Helmberger, Peter and Sidney Hoos. (1962) "Cooperative Enterprise and Organization Theory." J. Farm Econ. 44:275-290 (May).

Law, Averill M. and W. David Kelton. (1982). *Simulation Modeling And Analysis.* McGraw-Hill: New York.

Lohano, Heman D. (2002). *A Stochastic Dynamic Programming Analysis Of Farmland Investment And Financial Management.* Ph.D. Dissertation (unpublished). University of Minnesota, Department of Applied Economics.

McAfee, R. Preston, and John McMillan. (1987). "Auctions and Bidding." *Journal of Economic Literature* 25(2):699-738.

The Minneapolis / St. Paul Business Journal, "MN Corn Processors in sale talks with ADM." May 8, 2002.

Minnesota Dept. of Agriculture. (2003). "A Price Report of Ethanol and Corn Milling Products." *Market News Report.* August, 2003.

Minnesota Dept. of Finance. (2003). "FY 2004-2005 Budget Highlights."

Minnesota Agricultural Statistics. (2001) Minnesota Dept. of Agriculture: St. Paul, Minnesota.

Miranda, Mario J. and Paul L. Fackler. (2002). *Applied Computational Economics and Finance.* MIT Press: Cambridge, Mass.

Nautz, D. (1995). "Optimal Bidding in Multi-Unit Auctions with Many Bidders." *Economics Letters* 48:301-306.

Nautz, D. and E. Wolfstetter. (1997). "Bid Shading and risk aversion in multi-unit auctions with many bidders." 56 Econ. Letters 195-200.

Nelson, Robert G. and Steven C. Turner. (1995) "Experimental Examination of a Thin Market: Price Behavior in a Declining Terminal Market Revisited." *J. Agr. And Applied Econ.* 27 (1), July 1995: 149-160.

Pagano, Marco. (1989). "Endogenous Market Thinness and Stock Price Volatility." *Review of Economic Studies*, 56, 269-288.

Pratt, J. (1964). "Risk Aversion In The Large And In The Small." *Econometrica* 32:122-136.

Robison, Lindon J. and Peter J. Barry. (1987). *The Competitive Firm's Response To Risk.* Macmillan Publishing Company: New York.

Sexton, Richard J. (1986). "The Formation of Cooperatives: A Game-Theoretic Approach with Implications for Cooperative Finance, Decision Making, and Stability." *Amer.J.Agr.Econ.* 68:214-225.

Sporleder, Thomas L. and Michael D. Bailey. (2001). "Using Real Options to Evaluate Producer Investment in New Generation Cooperatives." AAEA 2001 Annual Meeting, Selected Paper.

Statz, John M. (1983). "The Cooperative as a Coalition: A Game-Theoretic Approach." *Amer.J.Agr.Econ.* 65:1084-89.

Stokey, Nancy L. and Robert E. Lucas (1989). *Recursive Methods in Economic Dynamics*. Harvard Univ. Press: Cambridge, Massachusetts.

Tiffany, Douglas G. (2003). "Ethanol and Dry Mill Spreadsheet." Iowa State University, Agricultural Marketing Resource Center.

Torgerson, Randall E., and Bruce J. Reynolds and Thomas W. Gray. (1998). "Evolution of Cooperative Thought, Theory, and Purpose." *Journal of Cooperatives* 11:1-20.

Torgerson, Randall E. (2001). "A Critical Look at New-Generation Cooperatives." *Rural Cooperatives*. Jan./Feb. 2001.

U.S. Dept. Agriculture / Rural Business – Cooperative Service. (1996). *Cooperative Historical Statistics*. Cooperative Information Report 1, section 26.

Ye, Su. (2002) "Economic Impact of the Ethanol Industry in Minnesota: Present Situations and Future Opportunities." Agricultural Marketing Services Division, Minnesota Department of Agriculture.

Zeuli, Kimberly Ann. (1998). *Value-Added Processing: An Assessment of the Risks and Returns To Farmers and Communities*. Ph.D. Dissertation. University of Minnesota.