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Operational Efficiency of a U.S./Canadian Wheat Pool: A Game Theory Analysis

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Abstract

The problem of declining wheat prices and excess supply has been the subject of recent economic studies partly because it coincides with the Federal Agriculture Improvement and Reform (FAIR) Act of 1996, and partly because efforts to decrease supply domestically have led to increased imports from Canada. This paper develops a game theory optimization model of market efficiency and derives conditions under which voluntary pooling is sustained for U.S./Canadian durum and hard red spring wheat producers. Analysis reveals that U.S. and Canadian farmers can increase farm returns with efficiency gains from pooling and by internalizing benefits from grain blending and logistics. The model is used to analyze diverse factors affecting the sustainability of such a pool.

Key Words: Voluntary pooling, game theory, efficiency gains, durum and HRS wheat marketing

Operational Efficiency of a U.S./Canadian Wheat Pool:
A Game Theory Analysis*

William E. Nganje, Won W. Koo, Joon J. Park, and Richard D. Taylor**

In 1998, North Dakota farmers proposed a marketing pool for durum and hard red spring (HRS) wheat produced in the United States and Canada. The main purpose of the pool would be to enhance farm income of wheat growers. Since 1996, durum and HRS wheat prices have been declining.[1] Declining wheat prices have resulted in decreasing net farm income and increasing farmers' reliance on government assistance and payments. In 1997, three out of ten farms had negative net farm income in North Dakota (Swenson). In 1999, government emergency and disaster payments for North Dakota were about $850 million (NDASS, 1999). Total disaster and insurance payments were $1.2 billion for about 31,000 farmers in North Dakota.

Declining wheat prices have been attributed mainly to decreased government protection by the new Federal Agricultural Improvement and Reform (FAIR) Act of 1996 and excess wheat supply. However, supply management, as an exclusive strategy used by U.S. farmers to raise wheat prices, was not effective. In theory, prices will increase as production and supply decreases. Nevertheless, declining price trends have persisted despite declining wheat acreage and production in the United States. The number of acres of HRS wheat planted in the United States has decreased by 23.4 percent or 4.68 million acres since 1996, and durum acreage declined by 320,000 acres or 8.8 percent in 1997 (USDA/ERS). Although, U.S. production and acreage under production have been declining since 1996, Canadian exports to the United States have been increasing (Figure 1).[2] The impact of Canadian exports on prices received by farmers in the United States is a highly debated issue and several studies (Sumner, Alston, and Gray;

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[1]Data from USDA-ERS indicate that U.S. durum and HRS wheat growers experienced a 41.1 percent and 34.6 percent decrease in price, respectively, from1996 to1999. In 1999, the durum price was at a record low of $2.75/bu.

[2]Wilson and Dahl pointed out that there are several reasons why Canadian exports to the United States have been increasing. Some of these reasons are increasing quality preferences by U.S. buyers, logistic incentives or shipment costs from Canada to the United States are lower than shipping to other offshore Canadian markets, and storage facilities are larger in the United States. Therefore, a joint marketing strategy between the United States and Canada may enable farmers to increase net farm income.

Babula, Jabara, and Reeder; and Koo, et al.) have been conducted.[3] Excess supply management to raise prices, exclusively by U.S. farmers, has been limited by the problem of fringe suppliers. Whenever wheat producing states like North Dakota decrease production to reduce wheat supply and raise prices, international competitors (like Canada) increase their wheat supply and exports to the United States and, consequently, prices decrease.

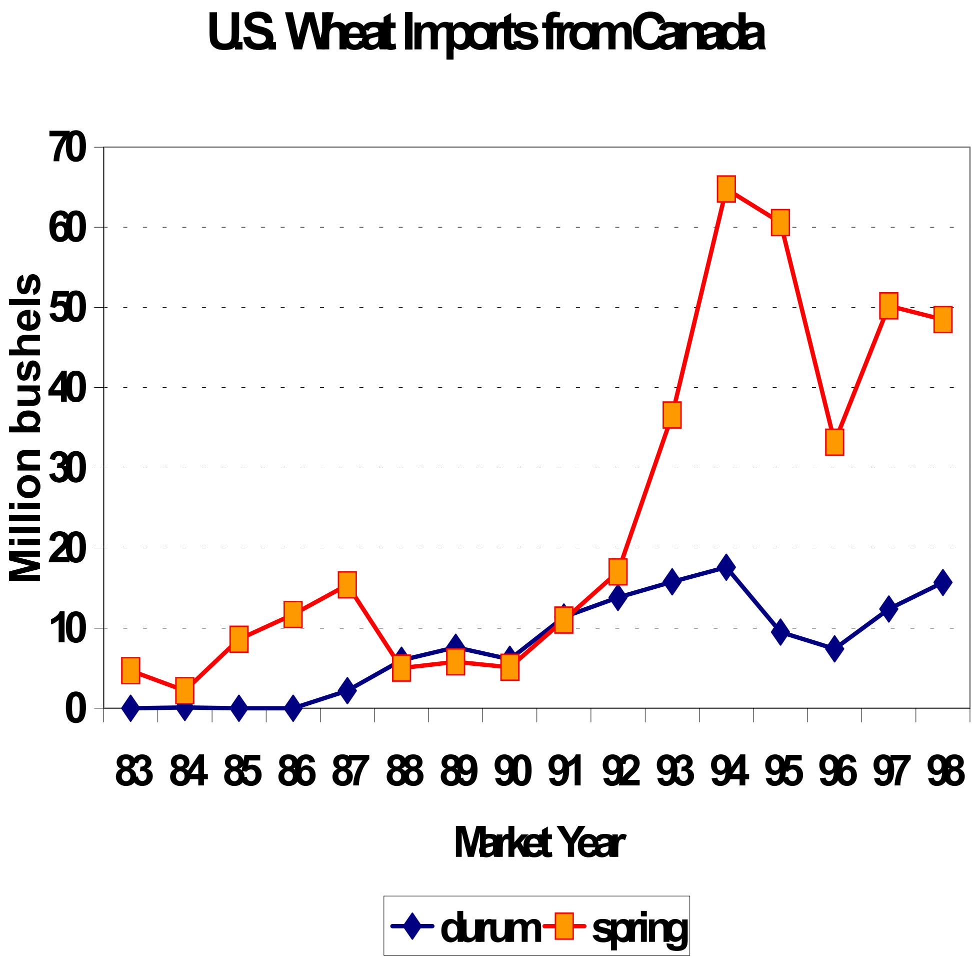

Figure 1. U.S. Wheat Imports from Canada

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[3]Some authors have argued that the price impact due to increased exports to the United States will be equivalent to the price impact if the CWB increases exports to the world market. Nevertheless, differences in transaction costs, elasticities, and price levels in both markets may affect prices in these markets differently.

Coupled with the limitation of supply management, declining wheat prices have coincided with the FAIR Act.[4] Although major U.S. competitors have some form of government protection [e.g., the Canadian Wheat Board (CWB) for Canadian farmers and a price floor for French and European Union (EU) wheat growers] the FAIR Act is anticipated to eliminate government protection for U.S. growers. This may imply an uneven playing field between U.S. wheat growers and their competitors. Data from the USDA/ERS suggest that major wheat producing nations and regions like Canada, the EU, and Australia have been experiencing increases in wheat exports while U.S. exports have been decreasing.

Hypothetically, it is assumed that as government protection decreases, as is the case with the FAIR Act, market power and margins shift from producers to originators and grain processors. A survey of the wheat industry by Wilson and Dahl reveals a shift of market power and margins from producers to originators or middlemen since the inception of the FAIR Act. One example of this shift is the shrinking revenue price for wheat as a proportion of finished wheat products, while the price of value-added wheat products like flour and pasta have not changed significantly and in some instances have increased (*Milling and Baking News*), despite declining wheat prices. A major challenge therefore, is to investigate whether the formation of a voluntary U.S./Canadian wheat pool can enable farmers to internalize benefits that are otherwise shifted to grain originators and processors.

This paper develops a game theoretical model of market efficiency that incorporates punishment strategies for fringe suppliers and derives conditions under which voluntary pooling is sustained for U.S. and Canadian durum and HRS wheat producers. This study analyzes joint marketing strategies for U.S. and Canadian durum and HRS wheat growers that can facilitate the transition from decreasing government protection by the FAIR Act into efficient market structures. Prior studies on voluntary pooling did not consider strategies that mitigate free rider or fringe suppliers' tendencies, and focused mainly on market power. We hypothesize in this study that farmers will increase net farm income through the U.S./Canadian voluntary wheat pool by mitigating free rider tendencies and internalizing efficiency gains from pooling that will otherwise be captured by grain originators and processors.

The paper is organized in four major sections. First, the background section presents information on the wheat pool and discusses the limitations of a pool when it depends entirely on market power. In the second section, a game theory model is developed and used to analyze efficiency gains from pooling with nonlinear pricing schemes as disincentives for free riders. Section three presents results from the game theory analysis and evaluates diverse factors affecting the sustainability of a U.S./Canadian wheat pool. Finally, some major conclusions and limitations are discussed.

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[4]Linsey, Director of Legislative Affairs, pointed out that many in Congress continue to call for a rewrite of the 1996 FAIR Act in the year 2001 because it is alleged that the Act's income safety net is inadequate during periods of low prices.

Background

There have been several meetings between U.S. and Canadian farmers and officers from the Prairie provinces and the Northern Plains to explore possibilities for cross-border cooperation, including a wheat pool.[5] In theory, a pool can be used to increase net income if it controls a significant market share and can practice price discrimination between various market segments. In principle, it may be unrealistic for pool members to rely entirely on market power to increase net farm income (Koo et al.). Previous attempts to create wheat pools in the Northern Plains have had limited success because of their emphasis on market power. In general, producers will seek to market their grain independently if they believe they can earn a higher return than offered by the pool. Since the pool return represents a weighted average of domestic and export sales, producers who are able to sell at the high domestic price (while avoiding the costs of pool participation) will choose to do so. For the pool to attract a sizable base of producers, it must offer advantages to offset this tendency.[6] Similar concerns arise with respect to free riders in other regions. To the extent that a higher domestic price elicits an increase in production in other regions, the market power of a pool is diminished.

Market Power Shortfall: A marketing pool is similar to a cartel that must deal with competitive fringe suppliers. Those who do not participate in the pool are fringe suppliers. They stand to gain if the pool succeeds in raising the market price, but incur some or none of the costs of participation; this makes them 'free-riders.'[7] The linear line D represents the demand schedule for a single time period, and S_p is the supply schedule of pool members (Figure 2). Given the supply of the competitive fringe members (schedule S_{np}), the excess demand curve (ED) for the pool can be drawn. MR is the marginal revenue associated with ED. The pool equates MR with the supply curve (S_p) and charges price P_1 to maximize its profit. At this price the pool's supply is $0Q_1$ and fringe suppliers will sell Q_1Q_2. The price for the fringe suppliers is

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[5]Although North Dakota produces 85 percent and 50 percent of the total U.S. durum and HRS wheat, respectively, the United States imports 25 and 45 million bushels of durum and HRS wheat, respectively, from Canada. With Canada being a major supplier of durum and HRS to the United States, a pool may operate more effectively with Canadian participation since the volume managed by the pool maybe crucial for its survival. North Dakota's market share for U.S. consumption of durum wheat is about 60 percent and 40 percent for HRS wheat, respectively.

[6]A potential structure for the pool, if created, will be like a cooperative. This structure will legally protect the pool from antitrust-monopolistic liabilities. A domestic example of such a structure is the California Rice Pool. A cross border example is the American Bison Cooperative. Vercammen, Fulton, and Hyde (1996) developed a non-linear pricing scheme for agricultural cooperatives that can be used as incentives to attract members. A quadratic unit cost function is used in this study to provide incentives from grain blending to pool members.

[7]Fringe suppliers or free riders are farmers from potential wheat producing states in the United States who are not members of the pool or farmers in wheat producing states who choose to join the pool but market a portion of their grain out of the pool.

$P_{1,}$ which is higher than in the absence of a pool. Without the pool, the fringe suppliers would only receive price $P_{f.}$

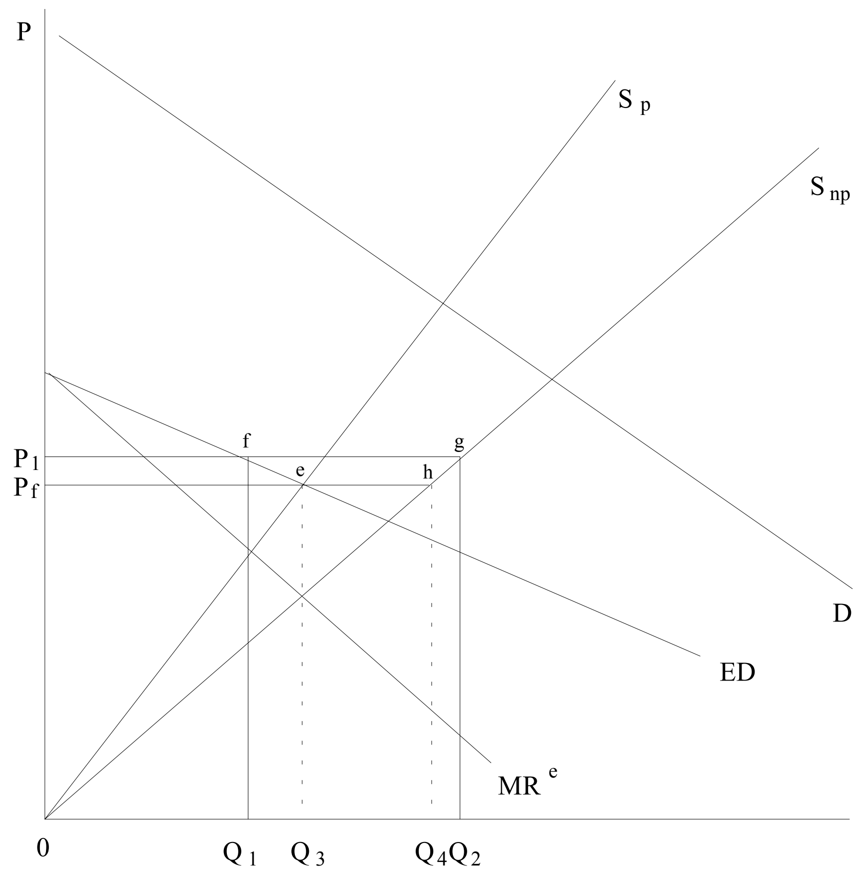

Figure 2. Relationship Between Pool Supplier and Competitive Fringe

Fringe suppliers can increase returns by pricing at P_1. At the free-trade price P_f, the fringe suppliers sell Q_3Q_4 while the pool sells $0Q_3$. Fringe suppliers gain proportionally more from the pool than do pool members, mainly because the fringe suppliers increase supply at the higher price, while members reduce supply. The fringe suppliers' revenue increases from area P_fhQ_40 to area P_1gQ_20, indicating that free riders are better off under the pool. The pool's revenue changes from area P_feQ_30 to area P_1fQ_10. Reduction in the pools' revenue, as a result of free riders, implies that it may be unrealistic to rely on market power as a long-run strategy to increase net farm income.

This suggests that long-term viability of the pool may depend on marketing and operational efficiencies or competitive advantages that are not shared by other grain trading firms. A survey on "Transitional Grain Companies: Evolution and Strategies in North America" by Wilson and Dahl revealed that the increase in demand for quality specificity instills pressure to increase the number of pools in the wheat industry. Among the areas where the pool could develop competitive advantages are grain blending, logistics, and strategic quality management.

Blending activities are recognized as one of the principal sources of profit for grain originators and merchandisers (Fulton and Hucq). Wheat is blended for a variety of grade and non-grade factors (e.g., protein, dockage, vomitoxin), based on premium and discount schedules that vary across markets and through time. Profit opportunities are greatest when there are shortages of high-quality grain or large price spreads for particular quality characteristics—as occurred in 1993/94, e.g., because of the scab outbreak.[8] Given the prevalence of blending in the grain industry, it is reasonable to think this could be an important activity for the wheat pool. To the extent that this replaces grain blending by private firms, the effect would be to capture new benefits for producers. Moreover, the pool's access to wheat stocks in a wide geographic area, combined with information on qualities available by location, would ensure greater blending opportunities than are available to local elevators or originators.

The pool may have additional advantages in the area of transportation and logistics. Unlike local elevators that must bid for grain, the pool could arrange for farmer deliveries at specified times and locations (shipping points) in order to meet sale commitments. With an assured supply, much of the logistical uncertainty is removed, forward sales are facilitated, and favorable shipping rates can be logged in more easily. In addition, the pool would have greater flexibility to assemble large shipments (e.g., by unit train) in response to short-term market incentives. With the cooperation of producers, a pool could have unparalleled access to information on the distribution of grain quality, by location, and across a geographical growing region. This would enable the efficient matching of supplies with quality requirements of individual buyers. Strategic quality management would entail the selective targeting of market segments and, in some cases, development of long-term supply arrangements based on customer requirements for quality assurance. Arguably, the pool would be better placed to enter long-term supply arrangements than private grain trading firms.

While the net benefits of grain blending, logistical advantages, and quality management are difficult to project, it is important to recognize that such benefits may be crucial to the long-term viability of the pool. The analysis in this paper develops these ideas more formally, using concepts of game theory. In the next section, we develop a game theory model to analyze efficiency gains from pooling and the sustainability of the U.S./Canadian wheat pool in a free rider environment.

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[8]Johnson and Nganje (1999) discussed the impact of scab infested grains from 1993-98 for the U.S. malting barley industry and analyzed blending opportunities under conditions of uncertainty. A similar model will be used to estimate blending opportunities for durum and HRS wheat for the pool.

Methodology and Data Sources

A major limitation of traditional voluntary pooling models is that they do not explicitly address the problem of fringe suppliers or free riders. The free-rider problem has been advanced in the literature by some authors (Schmitz, Gray, Schmitz, and Storey.; and Kraft, Furtan, and Tyrchniewicz) as a major reason why a voluntary wheat pool may not be feasible. Nevertheless, their analysis and propositions were based on market power rather than efficiency gains from pooling. The game theory model developed in this section incorporates a punishment strategy for free riders and focuses on marketing efficiency. Game theory has been used extensively in the literature to analyze market efficiency for perfect and imperfect competition (Osborne and Rubinstein). In this study, a game theory model is developed and used to determine the most profitable marketing strategy for U.S. and Canadian wheat growers; if they join or do not join the proposed U.S./Canadian wheat pool. The model is also used to analyze the conditions for sustainability of the wheat pool in a free-rider environment.

Theoretical Game Theory Model: In an infinitely repeated game, cooperation is the equilibrium outcome if a punishment strategy is defined so that it makes players worse-off when they deviate from the cooperative solution (Kreps, Milgrom, and Wilson). The infinitely repeated game is formulated on three solution concepts: 1) the Nash equilibrium solution, $\overline{\sigma}$, or the solution that is obtained when all players choose a "best response;" 2) the best strategy for each player, $\hat{\sigma}_i$, irrespective of other players' strategies; and 3) a mixed strategy outcome, σ^*, derived when some payers adopt mixed strategies–partially cooperate with the pool and free ride at the same time.

The model is developed in three major steps. First, we estimate the three game theory solutions for U.S. and Canadian farmers who decide to join or not to join the wheat pool. There are two sub-steps necessary to accomplish this first step. First, cartel and modified Cournot solutions are estimated for U.S. and Canadian farmers who decide to, or not to, join the wheat pool. Three optimization models are used in this sub-step to estimated cartel payoffs when farmers join the wheat pool, Cournot payoffs when farmers decide not to join the wheat pool, and Cournot payoffs for free riders. Restrictions on free riders payoffs are based on the assumption that free riders do not benefit from efficiency gains from blending and other logistical advantages offered by the pool. In the second sub-step, the Nash equilibrium solution, $\overline{\sigma}$, the best strategy for each player, $\hat{\sigma}_i$, and a mixed strategy outcome, σ^*, are determined using game theory concepts like best response (BR). The second major step is to estimate efficiency gains for U.S. and Canadian farmers who join the pool, given their best strategy. Finally, the conditions for sustainability of the pools' payoff are analyzed using the

Nash equilibrium solution, $\bar{\sigma}$, the best strategy for each player, $\hat{\sigma}_i$, and a mixed strategy outcome, σ^*.[9]

The U.S. and Canadian Wheat Pool Game: The three components of this game are the players, their strategies, and their payoffs for each strategy. There are two players in this game: U.S. and Canadian farmers. The objective of the pool is to provide incentives (efficiency gains) that make players better off by joining the pool.

There are two strategies for each player: U.S. farmers can either join the pool and be loyal to the pool by abiding to all contract specifications (C),[10] or join the pool and free-ride (CC); Canadian farmers can either join the pool (C), or not join the pool (DC).[11] Based on these strategies, the players receive payoffs (net revenue after deducting marketing cost and adding blending and logistical incentives) presented in Table 1. The payoffs are estimated using a modified Cournot or non-cooperative model and a cartel or cooperative model.[12] Payoffs ***a*** and ***e*** are cartel payoffs for U.S. farmers who adopt strategy C. Payoffs ***b*** and ***d*** are cartel payoffs for Canadian farmers who adopt strategy C; payoffs ***c*** and ***g*** are Cournot payoffs for U.S. farmers who adopt strategy CC; and payoffs ***f*** and ***h*** are Cournot payoffs for Canadian farmers who adopt

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[9]The condition for sustainability is based on the prisoner's dilemma. In a continuous game between two players, the expected utility from cooperating is greater than the expected utility from deviating and incurring punishment–in this case not benefitting from the pool's efficiency gains.

$$EU(PS_i) \geq EU(DEV) \iff \delta_i \geq \frac{ui(\hat{\sigma}_i,\ \sigma^*_{-i}) - ui(\sigma^*)}{ui(\hat{\sigma}_i, \sigma^*_{-i}) - ui(\bar{\sigma})}$$

Following the derivation from Nash, if the discount rate, δ_i is greater than the outcome in the right-hand side, then cooperation or joining the pool can be sustained with the defined punishment strategy.

[10]Most cooperatives, especially New Generation Cooperatives in the United States are closed contract cooperatives with delivery obligations. As stated earlier, the analysis in this study assumes the pool will be operated as a cooperative. A good example of such a cooperative between the United States and Canada is the North American Bison Cooperative, in North Dakota.

[11]For simplicity, we specify two strategies for each player rather than three: join the pool (C), do not join the pool (DC), and free ride (CC). We assume Canadian farmers will join the pool via the CWB and this will eliminate any free-rider problems from Canada. They can only join the pool (C) or not join the pool (DC). U.S. farmers who do not join the pool, or join the pool and free ride, play CC as strategy.

[12]Baumol (1967), pointed out that the assumption of quantity as the major decision variable in the original Cournot's model rather than quantity and price should be rectified in empirical analysis. One suggestion made by Baumol to relax this assumption is to impose price restrictions to the Cournot model. We modify the original Cournot model by imposing price, cost, and incentive restrictions.

strategy DC. In the proceeding section we develop three optimization models: 1) the cartel model to estimate payoffs (***a, b, e,*** and ***d***) for U.S. and Canadian farmers who join the pool, 2) a non-cooperative or Cournot model to estimate payoffs (***c*** and ***g***) for U.S. farmers who do not join the pool or free ride, and 3) a non-cooperative or Cournot model to estimate payoffs (***f*** and ***h***) for Canadian farmers if they do not join the pool.

Table 1. Strategies and Payoffs of Pool and Non-pool Members and Free Riders

U.S. Farmers (1)/ Canadian Farmers (2)	Join pool (C)	Join Pool and Free Ride (CC)
Join pool (C)	*a, b*	*c, d*
Don't join pool (DC)	*e, f*	*g, h*

a, b, c, d, e, f, g, and h are payoffs received by farmers for their respective strategies.

Model 1: Pool or Cartel Model for U.S. and Canadian Farmers: The objective (Equation 1) is to maximize the expected payoffs for U.S. and Canadian farmers jointly. In Equation 1, P_t is the expected price for all grains sold when the pool chooses its quantity/quality level, Q_{kt}, and the net expected payoff for each player is the product of the quantity/quality supplied (Q_{kt}) and the expected price (P_t) less the unit marketing costs (Uc_{kt}). The subscript k, represents the players: U.S. and Canadian producers, and t is time period.[13] The objective function is expressed as:

$$Max\ [Rev] = \sum_t \sum_k (P_t - UC_{kt})Q_{kt}, \qquad \text{where } k = 1,2, \quad t = 1,2,3,4. \tag{1}$$

This objective function is maximized subject to demand, supply, marketing costs, and incentive restrictions. Equation 2 is the inverse demand equation.

$$\beta_{k0} - \beta_{k1} Q_{tk} = P_t. \tag{2}$$

This imposes the restriction that enables prices to decrease as the players increase their wheat supply. This restriction is imposed because it is assumed the volume of grain that is handled by the pool is significant to affect market prices. Without this restriction, supply will increase indefinitely. The coefficients β_{k0} and β_{k1} are estimated using historic data from the National Agricultural Statistics Service (NASS). Equation 3 defines total quantity/quality supplied, Q*, as the sum of supply from U.S. and Canadian farmers: pool members, non-pool members, and free riders.

$$Q_t^* - \sum_k Q_{kt} = 0. \tag{3}$$

[13]Since net price received by farmers changes from year to year based on supply responses by free riders, a four-year time frame was used to analyze variability of returns each year (Koo et al.).

Equation 4 is a lag supply reaction function.

$$\delta_{k0}+\delta_{k1}(P_{t-1}-UC_{k,t-1})+\delta_{k2}Q_{k,t-1} = Q_{kt}. \qquad \textbf{(4)}$$

It limits the supply for any given year as a function of net expected price and quantity in the previous year. NASS data suggests that if prices in period t are higher, supply in period t+1 increases and vice versa. The supply response coefficients δ_{k0}, δ_{k1}, and δ_{k2} are estimated from historic NASS data. Equation 5 presents the unit cost constraint.

$$\alpha'_{k0}+\alpha'_{k1}Q_{kt}-\alpha'_{k2}Q^2_{kt} = UC_{kt}, \qquad \textbf{(5)}$$

where the coefficients $\acute{\alpha}_{k0}$, $\acute{\alpha}_{k1}$, and $\acute{\alpha}_{k2}$ are estimated from historic NASS data. The unit marketing cost, $\boldsymbol{UC_{kt}}$ is the marketing, logistics, and administrative costs of running the pool (Koo et al.). The unit marketing cost is quadratic in Q_{kt}. The quadratic formulation provides differential pricing for pool members, based on the quantity and quality they supply to the pool. This formulation enables pool members to capture efficiency gains from pooling (like blending margins and logistics benefits), while free riders and non-pool members do not. Although the main objective of cartels or pooling in the literature is to reduce quantity and increase price, the quadratic formulation of unit costs focuses on increasing pool price with efficiency gains from grain blending and logistics. Equation 6 presents quantity and quality premium restrictions from blending and other logistic advantages (Fulton and Hucq; Johnson and Nganje) enjoyed by pool members.[14]

$$UC_{t,NP}-Premium = UC_{t,p}. \qquad \textbf{(6)}$$

This constraint reduces the unit cost, Equation 5, for pool members. The unit cost for pool members (UC_p) is the difference between the unit marketing cost for running the pool and the benefits from grain blending and logistics. With the assumption that without the pool, pool members and non-pool members face the same marketing costs, the unit cost for pool members

[14]Although pool members incur the expenses of running the pool, they receive a premium for the quantity and quality of grains they supply to the pool. From the volume of grain the pool handles and its marketing expertise, it will be adept to blend off low quality grains and return a premium to its members. Such margins have been discussed and analyzed by Fulton and Hucq and Johnson and Nganje.

is the difference between the unit costs for non-pool members (UC_{NP}) and the ***Premium*** from blending and logistical benefits.[15] Model 1 was estimated using GAMS.

Model 2: Cournot Model for Free Riders (CC Strategy): The objective is to maximize returns for U.S. farmers who serve as free riders.

$$Max\ [Rev] = \sum_{t} (P_t - UC_{kt})Q_{kt}. \qquad \textbf{(7)}$$

The subscript k stands for all U.S. growers who free ride. Note that Canadian farmers can either join the pool or not because of the single desk selling of the CWB. This objective function is maximized, subject to the constraints in Equations 2 through 5. The quadratic cost structure in Equation 5 imposes higher unit operating costs to free riders because they do not enjoy efficiency gains from grain blending and logistics. In this model, Equation 6 is substituted by Equation 8.

$$Q_{kt} * (UC_{t,NPF} - Pr) = NonPool\ Cost_t. \qquad \textbf{(8)}$$

The subscript NFP represents non-pool members who free ride. Equation 8 restricts non-pool members and free riders in the United States to enjoy a premium ***Pr*** lower than that enjoyed by pool members. The total premium free riders receive, ***Pr,*** is lower than the premium received by pool members (***Premium***) since free riders can be pool members who market part of their grains with the pool and part independently.

Model 3: Cournot Model for Farmers Who Do Not Join the Pool (DC): This model is similar to Model 2, except for the fact that Equation 8 is substituted by Equation 9. The objective is to estimate payoffs of Canadian farmers if they do not join the pool.

$$Q_{kt} * UC_{t,NP} = NonPool\ Cost_t. \qquad \textbf{(9)}$$

In Equation 9, farmers incur prevailing marketing costs and earn zero premiums from pooling. This model is also estimated using GAMS software. Estimated payoffs from all three models are

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[15]There are three methods used to approximate blending margins and logistical incentives from pooling. First, the net margin for small and large grain elevators (SIC Code 5153) gives a range of 3 to 22 cents per bushel and the net margin for grain cleaning (SIC Code 0723) gives a range from 1.8 to 13.5 cents per bushel. Second, primary data from the industry and analysis by Johnson and Nganje revealed that blending margins for DON or scab affected grains can range from 0 to 23 cents per bushel. It should be noted that, during 1991-1997, producers in scab affected regions in the United States suffered a cumulative $1.3 billion loss. Losses for durum and HRS were estimated to be $73 and $806 million, respectively. Scab accounts for more than 30 percent of total grain discounts (Demcey and Nganje). Finally, prior blending models developed by Johnson and Nganje were used to estimate a range of 4.3 to 12.2 cents per bushel. The GAMS model uses a loop formulation to determine premium levels for the pool. At 4 cents per bushel and higher, the pool provides significant incentives for members and punishment for non-members.

used to derive the three game theory solutions indicated earlier. The conditions for sustainability of the pool are analyzed using these solutions.

Historic price and quantity data for durum and HRS wheat from 1990 to 1999 reported by the North Dakota and the National Agricultural Statistics Service (NDASS and USDA/ERS) are used to estimated payoffs from the three models. USDA/ERS has quantities of durum and HRS wheat produced in the United States and prices received by farmers. USDA/ERS also has data on total imports from Canada and total U.S. demand for HRS and durum wheat. These data were also used to estimate the coefficients for Equations 2, 4, and 5 (Table 2).

Table 2. Estimated Coefficients for Equations 2, 4, and 5

Coefficients for Inverse Demand Equation 2 (Values in parenthesis are T-values)	Coefficients for Supply Restriction Equation 4 (Values in parenthesis are T-Ratios)	Coefficients for Lagged Supply Restriction Equation 5 (Values in parenthesis are T-Ratios)
6.31* (28.42)	19.889** (39.01)	2.343* (7.43)
-0.0135** (-0.41)	22.908 (12.04)	-0.0423**(0.09)
	-0.0144* (0.15)	0.000135*(0.0014)
R^2 = 69.2%	R^2 = 88.4%	R^2 = 91.3%

* and ** imply significance at the 1% and 5% level, respectively.

Results and Discussion

Results from the cartel and modified Cournot models are summarized in Tables 3 and 4 for durum and HRS wheat, respectively. These results are presented in the three steps outlined in the model section. First, the payoffs for each strategy (models) are presented. A distinction is made between marginal revenue or price increases due to quantity restrictions and marginal revenue increases due to efficiency gains from blending and logistical advantages. Second, the three game theory solutions are used to determine the best strategy for U.S. and Canadian farmers. Finally, the conditions for sustaining such a pool with increased efficiency gains from pooling are evaluated.

Table 3. Estimated for Revenues (million $) for Durum Wheat Pool for All Players and Their Strategies

U.S. Farmers/ Canadian Farmers	Join Pool (C) Quantity (57.76 million bushels)	Join Pool and Free Ride (CC) Quantity (32.63 million bushels)
Cooperate with Pool (C) Quantity (25.13 million bushels)	258.77 , 112.58 (4.48), (4.48)	143.89 , 112.58 (4.41), (4.48)
Don't Join Pool (DC) Quantity (25.13 million bushels)	258.77 , 110.57 (4.48), (4.40)	143.89, 110.57 (4.41), (4.40)

The numbers in parentheses are dollars per bushel received from each strategy.

Table 4. Estimated for Revenues (million $) for HRS Wheat Pool for All Players and Their Strategies

U.S. Farmers/ Canadian Farmers	Join Pool (C) Quantity (140.93 million bushels)	Join Pool and Free Ride (CC) Quantity (95.95 million bushels)
Cooperate with Pool (C) Quantity (45 million bushels)	452.39 , 145.35 (3.23), (3.23)	305.44 , 145.35 (3.18), (3.23)
Don't Join Pool (DC) Quantity (45 million bushels)	452.39 , 143.10 (3.23), (3.18)	305.44, 143.10 (3.18), (3.18)

The numbers in parentheses are dollars per bushel received from each strategy.

Estimated payoffs for the Cournot model (DC strategy) are $110.57 million for 25.13 million bushels of durum wheat. This is equivalent to $4.40 per bushel. The estimated payoff for 45 million bushels of HRS wheat was $143.1 million or $3.18 per bushel.[16] This model's results serve as a baseline, compared to Models 1 and 2, in differentiating the marginal revenue impacts due to efficiency gains. This is because farmers adopting this strategy do not enjoy any efficiency gains from pooling.

Estimated payoffs for the Cournot model (CC strategy) are $143.89 million for 32.63 million bushels of durum wheat or $4.41 per bushel. The estimated payoff for 95.95 million bushels of HRS wheat was $305.44 million or $3.18 per bushel. The payoffs from this model are

[16]Estimated prices, per bushel, are much higher than farm prices but comparable to Minneapolis prices for top grades. This is due to two reasons: the assumption that the pool will be adept to blend off low quality grains and the fact that payoffs are four-year averages. Koo et al. noted that it will require at least four years for the pool to attain price stability given the reaction functions of fringe suppliers.

slightly higher than the payoffs from the baseline model for durum wheat because the model allows free riders to market some of their grains through the pool.

Results from the cartel strategy, C, show significant increases in revenue and price from the baseline strategy. Estimated payoffs for the cartel model (C strategy) are higher for U.S. and Canadian farmers: $258.77 million for 57.76 million bushels of durum wheat or $4.48 per bushel; $452.39 million for 140.93 million bushels of HRS wheat or $3.23 per bushel for U.S. farmers; $112.58 million for 25.13 million bushels of durum wheat or $4.48 per bushel; and $145.35 million for 45 million bushels of HRS wheat or $3.23 per bushel for Canadian farmers.

These results indicate that the best response for U.S. and Canadian farmers is to cooperate (Play C and C) and market durum wheat jointly in a voluntary pool (cartel solution or Model 1). Payoffs from this strategy first order stochastically dominates the Cournot payoffs, if farmers do not join the pool or if they serve as free riders (Models 2 and 3). The cartel payoff yields $4.48 per bushel of durum wheat for U.S. and Canadian farmers on average, as compared to $4.41 and $4.40 per bushel for free riders or farmers who do not join the pool. The highest aggregate farm income for U.S. and Canadian durum wheat growers is derived using the cartel strategy. Similar results were obtained for HRS wheat (Table 4). The differences in payoffs and efficiency gains for durum and HRS wheat are due to the fact that the pool is able to internalize greater benefits from grain blending and logistical advantages with durum. There have been greater problems with the quality of durum produced in the United States as compared to HRS which is substitutable with hard red winter wheat. Estimated net revenues for durum and HRS wheat are greatest for pool members, followed by free riders, and non-pool members.

Figures 3 and 4 present simulated efficiency gains for durum and HRS wheat with increases in the wheat pool size. Efficiency gains for durum wheat increase as the pool's market share increases; gains attain a maximum value of $0.276 per bushel when the pool controls about 65 percent of the durum market share. The results are within the reported range of net returns for small and large grain originators, SIC Code 5153. Contrary to market power shortfalls presented in Figure 2, pool members enjoy higher marginal revenue because of efficiency gains from pooling and significant punishment strategies for free riders.

Conditions for Sustainability: Two sustainability conditions are discussed: a theoretical proof and using the three game theory solution discussed earlier. Suppose the players are not certain whether the pool will institute cooperation between U.S. and Canadian farmers in the long run ($T = +\infty$) and sustain long-run efficiency gains and higher prices. In other words, the participants are not positive that they will cooperate in the last period (T_n) even if they enjoy efficiency gains from cooperation in the prior periods. This is a serious question because players and pool members may be faced with opportunities that provide higher returns than the pool's returns in the short run. They may be enticed by these opportunities and not join the wheat pool (DC or CC).

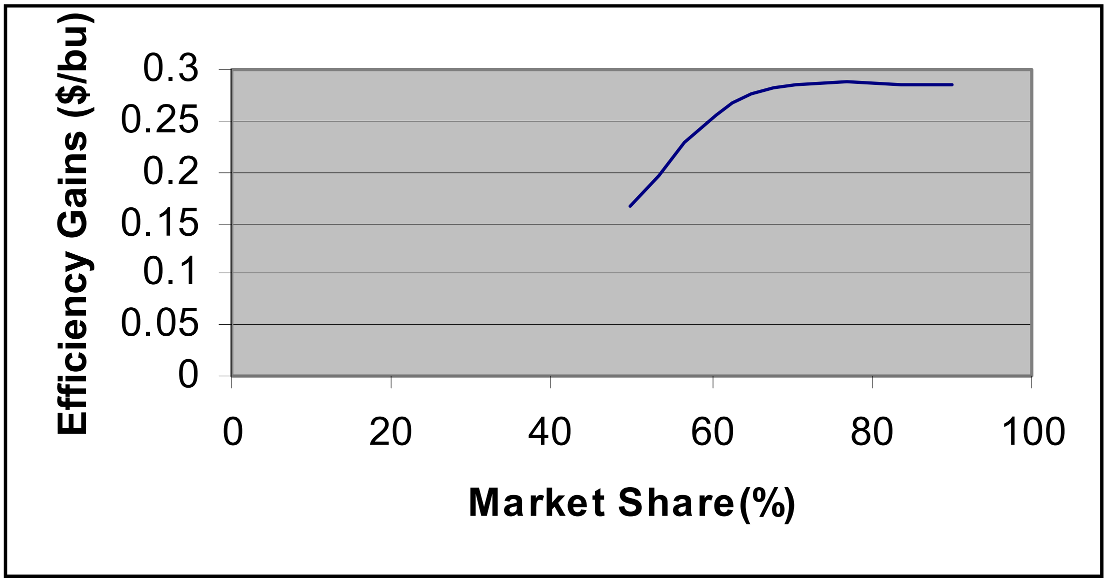

Figure 3. Estimated Efficiency Gains Versus Pool's Market Share for Durum Wheat

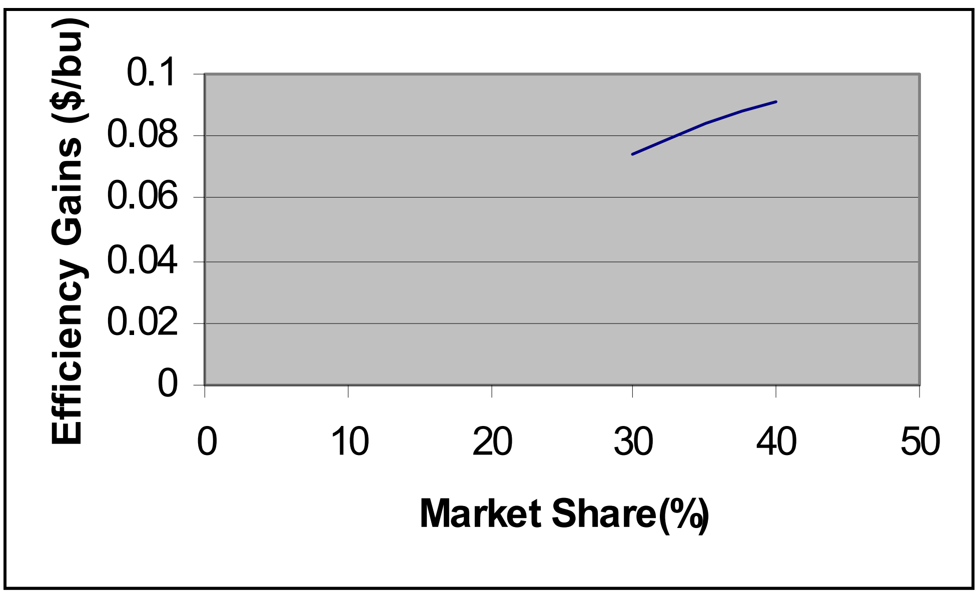

Figure 4. Estimated Efficiency Gains Versus Pool's Market Share for HRS Wheat

In this section, the Baby version of the Folk Theorem, introduced in the methodology section, is used to show that cooperation between U.S. and Canadian farmers (C) is the dominant strategy at period T_n. There are two ways this can be demonstrated. First, the results in Tables 3 and 4 are extended to cover n periods. The revenue at period T_n is discounted for each player using the net present value formula. This implies that the players are maximizing the present value of returns and consequently, there is no last period. The solution of the problem is simple and straightforward. At time t=0 players cooperate with the pool and earn higher returns. At t > 0, if non-cooperation has been played by either player, the other player plays non-cooperation as well or else cooperates. The punishment strategy is to cooperate until the other player deviates and then play non-cooperation forever. The net present value solution to this problem is to cooperate in period T_n. We used four periods in our GAMS model to estimate the payoffs and discounted these returns using an 8.5 percent discount rate (prevailing rate for wheat growers). The results showed the Nash equilibrium strategy for both players was to cooperate; join the wheat pool. As the number of periods increases, cooperation is still the best strategy if the discount rate is not too large.[17]

In the second proof, we used the three solution concepts (Nash equilibrium solution, $\overline{\sigma}$; the best strategy for each player, $\hat{\sigma}_i$; and the mixed strategy outcome σ*) to show that the punishment strategy (not enjoying the efficiency gains from pooling) is greater than the deviation strategy or not joining the pool. That is, the expected utility of the punishment strategy is greater than the expected utility of the deviation strategy $EU(PS_i) \geq EU(DEV)$.

The results reveal that the Nash equilibrium outcome for the game is for U.S. and Canadian farmers to cooperate. For U.S. and Canadian farmers, cooperating with the pool strongly dominates non-cooperating (players receive $4.48 and $3.23 per bushel as opposed to $4.41 and $3.18 for durum and HRS wheat, respectively). The best strategy for either player, independent of the other player's strategy, is to cooperate or join the pool. The payoffs are the same as in the Nash equilibrium case. Finally, the dominant mixed strategy profile for each player is $4.48 and $3.23 per bushel for durum and HRS wheat, respectively. The estimated sustainability conditions for the durum or HRS wheat pool is zero.[18] This implies that with the discount rate, δ_i, greater than zero, the punishment strategy with efficiency gains for pooling (C) dominates the deviation strategy (DC or CC). The pool can be sustained with efficiency gains from pooling in the long run.

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[17]The difference between the present value with cooperation and without cooperation is $2\delta^T[-1 + \delta/(1-\delta)]$. This is positive if the discount rate (δ) < 0.5.

[18]That is (4.48-4.48)/(4.48-4.48) = 0 for durum wheat and (3.23-3.23)/(3.23-3.23) = 0 for HRS wheat.

Conclusions

In 1998, North Dakota farmers proposed a marketing pool for durum and hard red spring (HRS) wheat produced in the United States and Canada as a joint marketing strategy to increase net farm income. Net farm income has been decreasing since 1996 with declining durum and HRS wheat prices. Efforts to raise prices via excess supply management have not been promising because of fringe suppliers. This paper develops a game theory optimization model to determine whether marketing durum and HRS wheat through the U.S./Canadian voluntary wheat pool is the best strategy to increase net farm income in a free-rider environment. Results reveal that the Nash equilibrium outcome, the mixed strategy outcome, and the best strategy for U.S. and Canadian farmers is to market their grains through the proposed wheat pool. The benefits of pooling are greatest for durum wheat; durum wheat pool presents greater blending and logistic opportunities due to quality problems when compared to HRS wheat.

Although, the wheat pool can be sustained with efficiency gains from pooling, it may encounter legal and policy barriers as a result of the CWB. Nevertheless, a cross border pool or cooperative like the North American Bison Cooperative is an example of the U.S./Canadian voluntary pool that has increased efficiency gains for U.S./Canadian farmers. Although proponents of the CWB suggest that voluntary pooling will be infeasible because of fringe suppliers or free-rider problems, this game theory analysis suggests the contrary on the grounds of efficiency gains from pooling rather than market power. With the inception of the FAIR Act in 1996, U.S. farmers need alternative marketing strategies to increase and sustain farm income rather than continuous reliance on government assistance. The study suggests the use of voluntary pooling as an alternative means to increase net farm income by increasing marketing efficiency of wheat growers in the United States and Canada.

References

Babula, R.A., Cathy L. Jabara, and John Reeder. "Role of Empirical Evidence in U.S./Canada Dispute of U.S. Imports of Wheat, Wheat Flour, and Semolina." *Agribusiness*, Vol. 12, No. 2, 183-199 (1996).

Baumol, William J. "Business Behavior, Value and Growth," Rev. ed. New York: Harcourt, Brace & World, 1967.

Fulton, Murray, and Andre Hucq. "The Economics of Blending and Grading." The Economics of Western Grain Transportation and Handling. 1996 Van Vliet Publication Series, Department of Agricultural Economics, University of Saskatchewan,1996.

Johnson, D. Demcey, and William E. Nganje. "Impacts of DON in the Malting Barley Supply Chain: Aggregate Costs and Firm-Level Risks." Agricultural Economics Misc. Report No. 187, Department of Agricultural Economics, North Dakota State University, Fargo, April 2000.

Koo, W. Won, William E. Nganje, Demcey D. Johnson, Joon Park, and Richard D. Taylor. "Economic Analysis of Proposed North Dakota Wheat Pool." Agricultural Economics Report No. 410, Department of Agricultural Economics, North Dakota State University, Fargo, January 1999.

Kraft, D.F., W.H. Furtan, and E.W. Tyrchniewicz. "Performance Evaluation of the Canadian Wheat Board." Manitoba: Canadian Wheat Board, 1996.

Kreps, D., P. Milgrom, and R. Wilson. "Rational Cooperation in nth Finitely Repeated Prisoners' Dilemma." *Journal of Economic Theory* 27:245-79, 1982.

Milling and Baking News. "Baking Industry Statistics." 1997, 1998, and 1999.

Nash, J. 1953. "Two-Person Cooperative Games." Econometrica 21:128-40.

Osborne and Rubinstein, A. "A Perfect Equilibrium in Bargaining Models." *Econometrica* 50:97-109. 1982.

Schmitz, T.G., R. Gray, T. Schmitz, and G. Storey. "The CWB and Barley Marketing: Price Pooling and Single -Desk Selling." Winnipeg, Manitoba: Canadian Wheat Board, January 1997.

Sumner, D., J. Alston, and R. Gray. " A Quantitative Analysis of the Effects of Wheat Imports on the U.S. Markets for Wheat Including the Impact on Deficiency Payments," Analysis submitted to the U.S. International Trade Commission on behalf of the CWB et al. As Interested Parties to Investigation No. 22-54, Washington, DC, April 28, 1994.

Swenson, Andrew. “Financial Characteristics of North Dakota Farms.” Agricultural Economics Report No. 403, Department of Agricultural Economics, North Dakota State University, Fargo, August 1998.

U.S. Department of Agriculture. National Agricultural Statistics Service and North Dakota Agricultural Statistics Service, for various years, 1999.

Vercammen, Fulton, and Hyde. “Cooperative Marketing Strategies,”*American Journal of Agricultural Economics* Vol. 78, No. 4(November 1996):944-53.

Wilson, William W., and Bruce L. Dahl. “Transnational Grain Companies: Evolution and Strategies in North America,” Agricultural Economics Report No. 412, Department of Agricultural Economics, North Dakota State University, Fargo, February 1999.