Operational Efficiency of US/Canada Wheat Pool: A Game Theory Analysis

By
Nganje E. William, Won Koo, Demcey Johnson, Joon Park, and Richard Taylor[1]

Annual Meeting of Western Agricultural Economics Association
Vancouver, Canada
June 29- July3, 2000

Address:	William E. Nganje, Ph.D
	Department of Agricultural Economics
	North Dakota State University
	Fargo, ND 58105-5636
Email:	wnganje@ndsuext.nodak.edu
Phone:	701/231-7459
Fax:	701/231-7400

[1] The authors are Assistant Professor, Professor, Post Doctoral Research Associate, and Research Associate at North Dakota State University.

Operational Efficiency of US/Canada Wheat Pool: A Game Theory Analysis

Abstract

This paper develops a game theory optimization model of market efficiency and derives conditions under which voluntary pooling is sustained for US/Canada durum and hard red spring wheat producers. Analysis reveals that United States 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, US/Canada wheat trade

Operational Efficiency of US/Canada Wheat Pool: A Game Theory Analysis

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. 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. Declining wheat prices have caused many farmers to quit farming. In 1997 three out of ten farms had negative net farm income in North Dakota (Swenson). The number of acres planted for HRS wheat 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).

There are two major propositions about the causes of declining wheat prices: over-production, and reduced government protection under the 1996 Federal Agricultural Improvement and Reform Act (FAIR Act). Declining durum and HRS wheat prices have coincided with the new farm Act. On the other hand, declining price trends have persisted despite declining wheat acreage and production in the U.S. It is plausible that decreased government protection may have contributed to price variability. Also, the fact that prices of value-added wheat products like flour and pasta, have not changed significantly and in some instances have increased (Milling and Baking News, multiple) suggests that margins are shifting from producers to either grain merchandisers or processors. This is the primary motivation of this paper: to investigate whether the formation of a wheat pool can enable farmers to internalize benefits that are otherwise shifted to grain merchandisers or processors, and investigate how the proposed wheat pool can sustain long-run profits and prices. Another economic motivation for a pool would be to decrease farmer' reliance on government assistance and payments.[1] This paper analyzes effective economic strategies and solutions to long-run price and revenue stability to wheat growers through the proposed U.S./Canada wheat pool. The rest of the paper is organized in four major sections. First, we discuss background and prior feasibility studies of the wheat pool. Second, the limitations of a pool depending entirely on market power (under conditions of imperfect competition) are developed. In the third section, we develop a game theory model to analyze efficiency gains from pooling with nonlinear pricing schemes. Finally, the model is used to analyze diverse factors affecting the sustainability of U.S./Canada wheat pool.

Background

There have been several meetings between U.S./Canadian farmers and officers from the Prairie provinces and the Northern plains to explore possibilities for cross-border cooperation, including a wheat pool.[2] Although U.S. production and acreage under production have been declining since 1996, Canadian exports to the United States have been increasing (Figure 1). The impact of Canadian exports on prices received by farmers and net farm income in the United States is a highly debated issue and several studies (Sumner, Alston, and Gray; Babula, Jabara, and Reeder; and Koo, among others) have been conducted. In theory, a pool can be used to increase net income if it controls a significant share of production and can practice price discrimination between various market segments. Cooperation between Canadian and Northern Plain farmers may enable the pool to control more than 50 percent of the durum and HRS production. In principle, it maybe 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 Plain 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.[3] 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.

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. Among the areas where the pool could develop competitive advantages are grain blending, logistics, and strategic quality management. 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.

Market Power Shortfalls

Several authors have discussed the limitations a pool may face in its attempt to earn higher prices via market power. Examples of these limitations that may apply to the U.S./Canada wheat pool are free rider problem (Koo et al.),[4] and imperfect competition (Sexton and Zhang). These two shortfalls are discussed to provide economic and theoretical justification of efficiency gains analysis in a game theory framework. First, the shortfalls due to free-riders are discussed graphically. 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 none of the costs of participation; this makes them 'free-riders'. 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 facing pool members can be drawn. MR is the marginal revenue associated with ED. The pool will equate MR with the supply curve S_p and charge 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 P_1, which is higher than in the absence of a pool. Without the pool, the fringe would only receive price P_f.

Fringe suppliers can increase returns by pricing at the pool price 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; this is 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. This implies that long-run price increases may not be sustained by the pool if pool members increase supply.

Second, Sexton and Zhang provide a detailed discussion of price determination under conditions of imperfect competition. They show that under imperfect competition the benefits from commercialization are captured by middlemen-grain merchandisers or processors in this case. There are several large grain merchandisers and processors in the United States and Canada that the pool will compete against.[5] These companies may offer incentives to farmers to serve as fringe suppliers to the pool. Consequently, the pool has to develop sustainable competitive advantages to compete in an imperfect environment. The pool can internalize blending and logistic benefits by providing the functions of the middlemen. Thus, long-run sustainability of the pool may come to depend solely on efficiency gains and good business savvy. The free-rider problem and imperfect competition have been advanced in the literature by many authors (Schmitz et al. and Kraft et al) as reasons why a voluntary pool may not succeed. Their analysis and propositions were based on market power rather that efficiency gains from pooling. In the next section, we develop a game theory model of market efficiency to analyze the sustainability of a wheat pool in a free-rider environment.

Methodology and Data Sources

Game theory has been used extensively in the literature to analyze market efficiency under alternative market conditions (Osborne and Rubinstein). In this study, game theory is used to determine and analyze the conditions for sustainability of the U.S./Canada wheat pool under alternative incentive schemes for pool members and punishment strategies for non-pool members. A major limitation of the U.S./Canada wheat pool discussed in section 2 is the free-rider problem. Game theory suggests a punishment strategy that can overcome the free-rider problem. Free-riders do not receive the efficiency gains from grain blending and logistical advantages of the pool.

Blending activities are recognized as one of the principal sources of profit for grain elevators 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, for example, because of the scab outbreak.[6] 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.

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. A game theory model is used to analyze short and long run sustainable conditions given free riders or fringe suppliers and to determine whether farmers are better off joining a wheat pool.

Baby Version of the Folk Theorem: 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, 1982). The infinitely repeated game is formulated on three solution concepts: 1) the Nash equilibrium solution, $\bar{o}$, or the solution that is obtained when all players choose a "best response," 2) the best strategy for each player, $\hat{o}_i$, irrespective of other players' strategies, and 3) a mixed strategy outcome, ó*, derived when some payers partially cooperate with the pool and free ride at the same time. The three components of this game theory model 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 providing all their output volume to the pool (C), or not join the pool or join the pool and free-ride (CC); Canadian farmers can either join the pool (C), or not join the pool (DC). We assume there are no free-rider problems with Canadian farmers because of the single desk selling role of the Canadian Wheat Board (CWB). Based on these strategies, the players receive payoffs (net revenue after deducting marketing cost) presented in Table 1. The payoffs are estimated using the Cournnot or non-cooperative model and the cartel or cooperative model. Payoffs ***a*** and ***e*** are cartel revenues for U.S. farmers who join the pool and have the pool market all their grains. Payoffs ***b*** and ***d*** are cartel revenues for Canadian farmers who join the pool and have the pool market their grains. Payoffs ***c*** and ***g*** are Cournot payoffs for U.S. farmers who join the pool and free ride (the pool only markets a portion of their grains). Payoffs ***f*** and ***h*** are Cournot payoffs for Canadian farmers who do not join the pool. In the proceeding section we develop three optimization models to derive, 1) the cartel payoffs (***a, b, e,*** and ***d***) for U.S. and Canadian farmers, 2) a non-cooperative or cournot payoff (***c*** and ***g***) for U.S. farmers, and 3) a non-cooperative or cournot payoff (***f*** and ***h***) for Canadian growers.

Model 1: Pool Model for U.S./Canadian Farmers: The objective (equation 1) is to maximize the expected payoff for U.S. and Canadian farmers jointly. In equation 1, P_t is the expected price for low and high quality grains received by farmers from the U.S. domestic market and the world market.[7] The net expected payoff for each player is the product of the quantity supplied (Q_{kt}) by that player and the expected price(P_t) less the unit marketing costs (UC_{kt}). The unit marketing cost is quadratic in quantity. The quadratic formulation provides differential pricing for pool, non-pool members, and free riders. This formulation enables pool members to capture most of the efficiency gains from pooling (like blending margins), 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 also on increasing pool price with efficiency gains from grain blending and logistics. Since net price received by farmers change from year to year based on supply responses by free riders, we incorporate the time component to analyze variability of returns each year.

$$\boldsymbol{Max\ [Rev] = \sum_t \sum_k (P_t - UC_{kt})Q_{kt}.} \qquad \textbf{(1)}$$

Where k stands for all US and Canadian producers who join the pool. This objective function is maximized subject to the following constraints:

$$\boldsymbol{\hat{a}_{k0} - \hat{a}_{k1} Q_{tk} = P_t.} \qquad \textbf{(2)}$$

Equation 2 is the inverse demand equation. This imposes the restriction that enables prices to decrease as the players increase their wheat supply. Without this restriction, supply will increase indefinitely. The coefficients $\hat{a}_{k0}$ and $\hat{a}_{k1}$ are estimated using historic data from the National Agricultural Statistic Service (NASS).

$$\boldsymbol{Q_t^{*} - \sum_k Q_{kt} = 0.} \qquad \textbf{(3)}$$

Equation 3 defines total quantity supplied, Q* as the sum of supply from pool members, non-pool members, and free riders from the US and Canada. Equation 4 is a lag supply reaction function.

$$\boldsymbol{\ddot{a}_{k0} + \ddot{a}_{k1}(P_{t-1} - UC_{k,t-1}) + \ddot{a}_{k2} Q_{k,t-1} = Q_{kt}.}$$

It limits the supply for any given year as a function of net expected price and quantity in the previous year. The supply response coefficients $\ddot{a}_{k0}$, $\ddot{a}_{k1}$, and $\ddot{a}_{k2}$ are estimated from historic NASS data. The estimated quadratic unit costs constraint is presented in equation 5.

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

where the coefficients $Ü_{k0}$, $Ü_{k1}$, and $Ü_{k2}$ 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. 1999). This constraint and equation 6 impose restrictions that enable pool members to incur a lower per unit marketing cost than non-pool members. The cost is structured in a manner that permits pool members to enjoy the lowest costs on the quadratic cost curve (equation 5). In practice pool members will receive quantity and quality premium from blending and other logistic advantages (Fulton and Hucq; and Johnson and Nganje).[8] Free riders and non-pool members incur higher per unit cost because individually they do not enjoy efficiency gains from blending and logistics. An example is the quantity incentive. If pool costs are maintained constant and the volume of grains handled by the pool increases, then the pool will enjoy scale advantages. These advantages can be passed on to members proportionally to the quantities they supply to the pool.

$$\boldsymbol{UC_{NP} - Premium = UC_p.} \qquad \textbf{(6)}$$

Equation 6 imposes the restriction that penalizes non-pool members from benefitting from blending and logistical advantages of the pool. 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 is the difference between the unit costs for non-pool members (UC_{NP}) and the ***Premium*** from blending and logistical benefits. A premium range from 0- 21 cents per bushel was estimated based on crop quality data from North Dakota Agricultural Statistics Service (NDASS) and discount schedules for a major quality characteristic (DON).[9] Equation 1 was estimated using Gams software and the model was feasible for net premiums greater than 4 cents per bushel.

Model 2: Cournot Model for U.S. Farmers: This model is used to estimate the revenue of farmers who join the pool and market some grain outside of the pool or farmers who decide to partially free-ride. The objective is to maximize returns for free riders.

$$Max\ [Rev] = \sum_t (P_t - UC_{kt})Q_{kt}. \tag{7}$$

Where K stands for all US growers who free ride. Canadian farmers can either join the pool or not because of the single desk selling on the Canadian Wheat Board (CWB). This model is constrained by equation 2 through 6 with an additional constraint for the cost incurred by free riders. Although free-riders incur fixed and operating expenses for running the pool, they enjoy only partial efficiency for the portion of their gains marketed by the pool. The quadratic cost structure in equation 5, penalize farmers for acting as free riders. The additional constraint is:

$$Q_k * (UC_{NPF} - Pr) = NonPool\ Cost. \tag{8}$$

Equation 8 restricts non-pool members and free-riders in the U.S. to enjoy a premium ***Pr*** lower than that enjoyed by pool members. In practice, and in our GAMS formulation, this group of farmers incurs all marketing costs for the portion of their grain they market out of the pool and incur some pool cost for the portion they market through the pool, but enjoy efficiency gains only for the portion of grains they market through the pool. Consequently, the total premium they receive (***Pr***) is lower than the premium received by pool members (***Premium***).

Model 3: Cournot Model for Canadian Farmers: This model is used to estimate the revenue of Canadian farmers if they do not join the pool. They incur marketing costs (UC_{kt}).

$$Max\ [Rev] = \sum_t (P_t - UC_{kt})Q_{kt}, \tag{9}$$

Where k is all Canadian or US farmers who do not join the pool. This objective function is maximized subject to an additional cost constraint given by:

$$Q_k * UC_{NP} = NonPool\ Cost. \tag{10}$$

In equation 10 the farmers incur prevailing marketing costs and earn zero premium from pooling. This model is also estimated using GAMS software. The estimated revenues are used to derive solutions for the game theoretical model and conditions for sustainability of the pool.

The analysis used historic price and quantity data from 1990 to 1999 reported by the North Dakota and the National Agricultural Statistics Service(NDASS and NASS).[10] NASS has data on the quantities produced and prices received by farmers for all durum and HRS wheat producing States in the United States and the aggregate for the whole U.S. NDASS provides production and price data for durum and HRS across years and for all 9 North Dakota crop reporting districts (NASS). NASS also has data on total imports from Canada and total U.S.

demand for HRS and durum wheat. These data were used to estimate the coefficients for equations 2, 4, and 5 (Table 2).

Results and Discussion

The results from the cartel and Cournot outcomes are presented and discussed in this section. Results of the estimated payoffs for durum wheat are summarized in Table 3. 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 serve as free riders. The cartel payoff yields \$4.48 per bushel for US 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 US and Canadian durum wheat growers is derived using the cartel strategy. Similar results are 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 by handling larger volumes of durum wheat, compared to HRS 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 the estimated efficiency gains for durum and HRS wheat with increases in the wheat pool size. Efficiency gains for durum wheat increases as the pool's market share increases and attains a maximum value of \$0.276/bu when the pool controls about 65% market share. The results are consistent with net returns for small and large grain elevators, reported on SIC code 5153. It should be noted also that, as the pool handles larger volumes of grains, its efficiency gains increase. Efficiency gains for HRS wheat increase as the pool's market share increases, but estimates are smaller than those for durum wheat because the pool is anticipated to handle a larger durum wheat market share. The pool should envisage efficiency gains from blending and logistical advantages as potential long-run strategies for durum and HRS wheat, rather than relying entirely on market power.

Conditions for Sustainability: Suppose the players are not certain that the pool will institute cooperation between U.S. and Canadian farmers forever ($T = +\infty$) 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).

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 Table 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 cooperate. The punishment strategy is to cooperate until the other player, doesn't and play non-cooperation forever. The net present value solution to this problem is to cooperate in period T_n. We used five periods in our Gams model to estimate the payoffs and discounted this returns using 8.5% discount rate (prevailing rate for wheat growers). The results showed the Nash equilibrium strategy for both players was still to cooperate and join the pool. As the number of periods increases, cooperation is still the best strategy if the discount rate is not too large.[11] This model incorporated supply response, based on price elasticities of supply and demand for durum and HRS wheats.

In the second proof, we used the three solution concepts (Nash equilibrium solution, $\bar{o}$; the best strategy for each player, $\hat{o}_i$; and the mixed strategy outcome ó*) 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 ($EU(PS_i) \geq EU(DEV)$, (See Appendix 1 for mathematical derivation.)

The results reveal that the Nash equilibrium outcome for the game is for the US 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 $3.21 per bushel for durum and HRS wheat respectively. Therefore, if the pool internalizes efficiency gains currently captured by grain handlers, it may be sustained in the long-run.[12]

Conclusion

This paper develops a game theory optimization model of market efficiency to derive conditions under which voluntary pooling is sustained for US/Canada durum and hard red spring wheat producers. The results reveal that the Nash equilibrium outcome for the game is for the US and Canadian farmers to form a wheat pool. The benefits of pooling are greatest for durum wheat as compared to HRS wheat. In addition, the game theory dynamic analysis reveals that players will cooperate and join the pool if they believe it will last indefinitely. Using supply response and results from sensitivity analysis of model findings, it can be concluded the wheat pool will increase net farm income, but requires four to five years to cover setup expenses and be self sustaining in the long run. Although, the wheat pool may be economically viable, legal and policy barriers may impede such a structure. The North American Bison Cooperative is an example of U.S./Canada pool that has improved marketing efficiency for U.S./Canadian farmers. A major limitation at this time may be due to the presence of the Canadian Wheat Board. Although proponents of the CWB suggest that voluntary pooling will be infeasible because of free rider problems, this article presents a game theory approach that can be used to resolve that issue. Also, arguments against voluntary pooling have only evaluated the effectiveness of the pool from a market power standpoint without considering market efficiency gains. With the institution of the FAIR Act in 1996, US farmers need alternative strategies to increase and sustain farm income rather than continue reliance government subsidies. The study suggests the use of a voluntary pooling as an alternative means to increase net farm income by increasing marketing efficiency of wheat growers in the United States and Canada.

Appendix 1

1. Let r = (ui, ∑i)$_{iEI}$ be the strategic form of a game. Suppose $\bar{ō}$ is a NE strategy profile for r. Let ó* be a strategy profile satisfying ui (ó*) > ui$(\bar{ō})$ (∀iEI). Let $\hat{ō}_i$ be a strategy for player i satisfying the following $\hat{ō}_i$ E $\frac{\text{aug max}}{\text{óiE}\sum \text{i}}$ ui(ó$_i$,ó$^*_{-i}$) (∀iEI).

2. Now consider the following strategy for player i at t = 0; play ó$^*_i$.

   At t ≥1; i ∫ ó* was realized in all previous periods, play ó$^*_i$ otherwise play $\bar{ō}_i$.

   Denote the above strategy by PS$_i$ (punishment strategy).

3. We would like to show that PS is a subgame, perfect equilibrium strategy profile.

   Suppose player i plays ó$^*_i$ at t ≤ t -1, and decides to deviate at time t. Then we have

t	0	1	2	t - 1	t	t + 1 . . . . .
i	c	c	c	c	deviate $\bar{ō}_{-i}$.	
others	c	c	c	$\bar{ō}_{-i}$	$\bar{ō}_{-i}$	

   By deviating from PS$_i$ at time t, the best player i can get is

$$\text{EU(DEV)} = \sum_{r=0}^{t-1} ä^t \text{ ui(ó}*) + ä^t \text{ ui}(\hat{ō}_i, ó^*_{-i}) + \sum_{r=t+1}^{\infty} ä^t \text{ ui}(\bar{ō}).$$

   If player i sticks to PS$_i$, then he gets

$$\text{EU(PS}_i) = \sum_{r=0}^{t-1} ä^t \text{ ui(ó}^*) + ä^t \text{ ui(ó}^*) + \sum_{r=t+1}^{\infty} ä^t \text{ ui(ó}^*).$$

4. EU(PS$_i$) ≥EU(DEV) <=> $ä_i \geq \frac{\text{ui}(\hat{ō}_i,\ ó^*_{-i}) - \text{ui(ó}^*)}{\text{ui}(\hat{ō}_i, ó^*_{-i}) - \text{ui}(\bar{ō})}$

References

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

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 Saskatcheewan.1996.

Vercammen, Fulton, and Hyde. "Cooperative Marketing Strategies "AJAE v78, n4(November 1996):944-53.

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. Reports No. 187, April 2000.

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

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

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, January 1999.

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

Swenson, Andy. "Financial Characteristics of North Dakota Farms." Agricultural Economics Report No. 403, August 1998.

Sexton, Richard J and Mingxia Zhang. "A Model of Price Determination for Fresh Produce with Application to Califonia Iceberg Lettuce." AJAE v78, n4(November 1996):924-43.

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

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

USDA/ERS. "National Agricultural Statistic Service." 1999.

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 payoff received by farmers if they adopt the different strategies.

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)
R^2 = 69.2%	-0.0144* (0.15)	0.000135*(0.0014)
	R^2 = 88.4%	R^2 = 91.3%

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

Table 3. Estimated for Revenues (million $) for Durum Wheat Pool for All Player 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 Player 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 (3.21), (3.23)	305.44 , 145.35 (3.18), (3.23)
Don't Join Pool (DC)Quantity (45 Million bushels)	452.39 , 143.10 (3.21), (3.18)	305.44, 143.10 (3.18), (3.18)

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

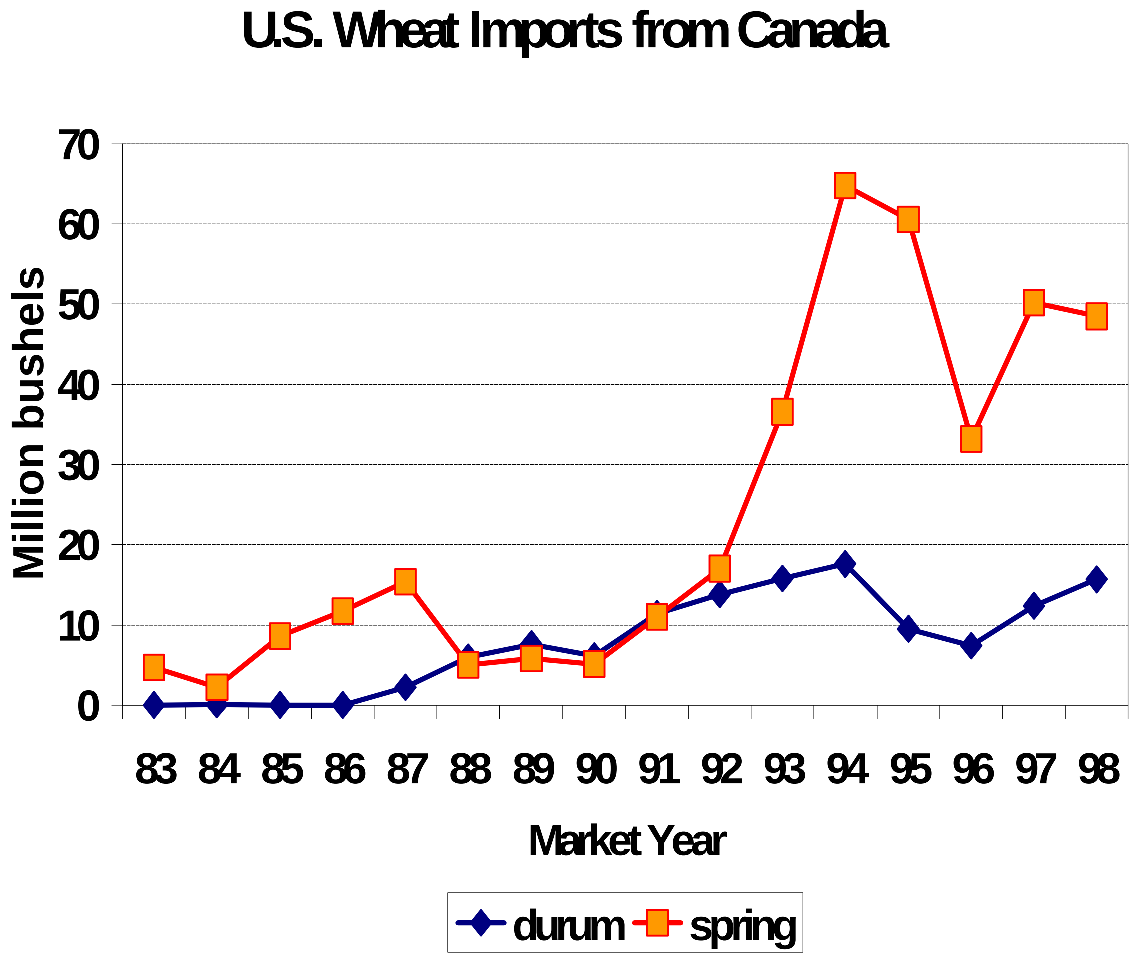


Figure 1. U.S. Wheat Imports From Canada

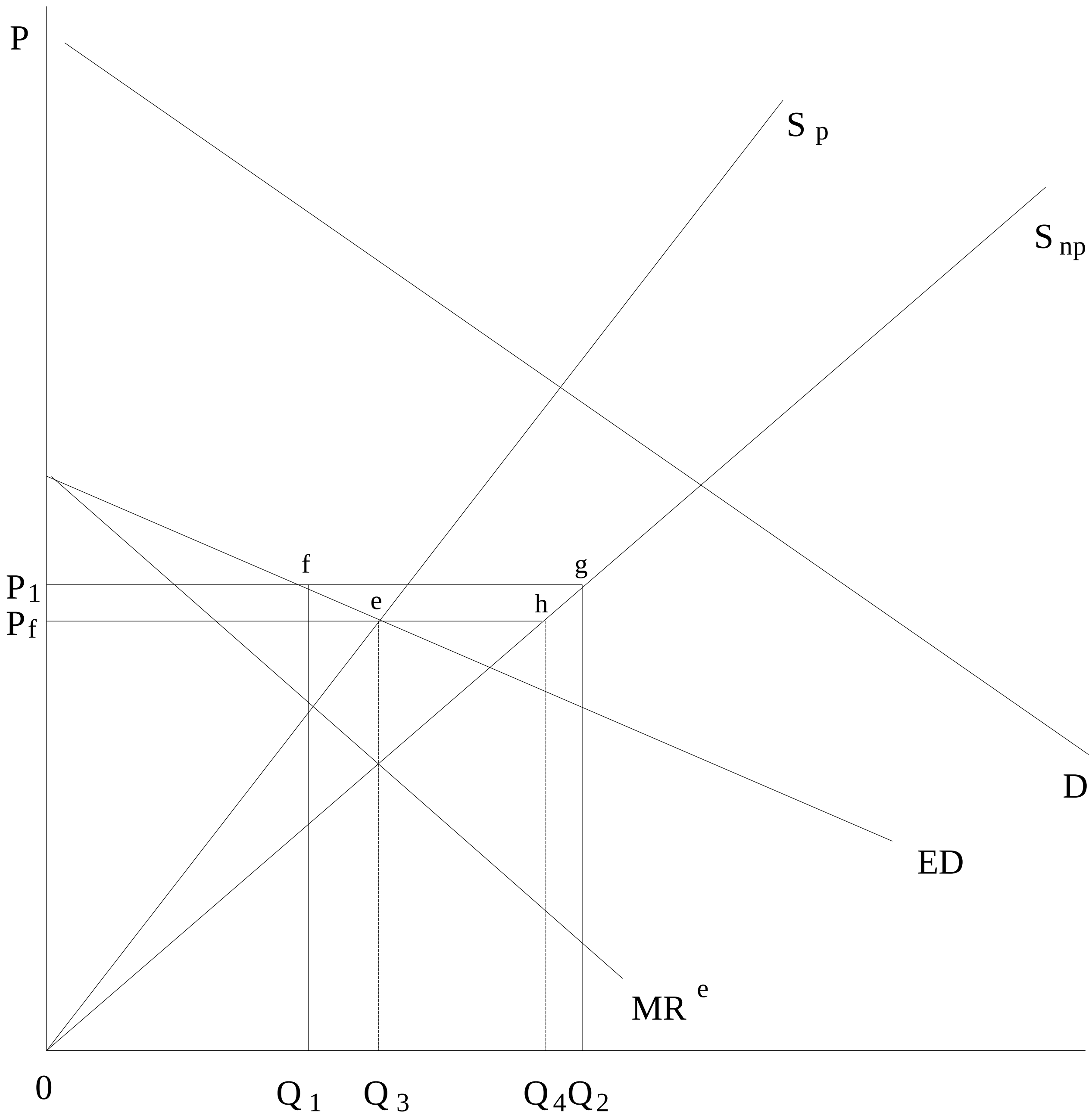


Figure 2. Relationship Between Pool Supplier and Competitive Fringe

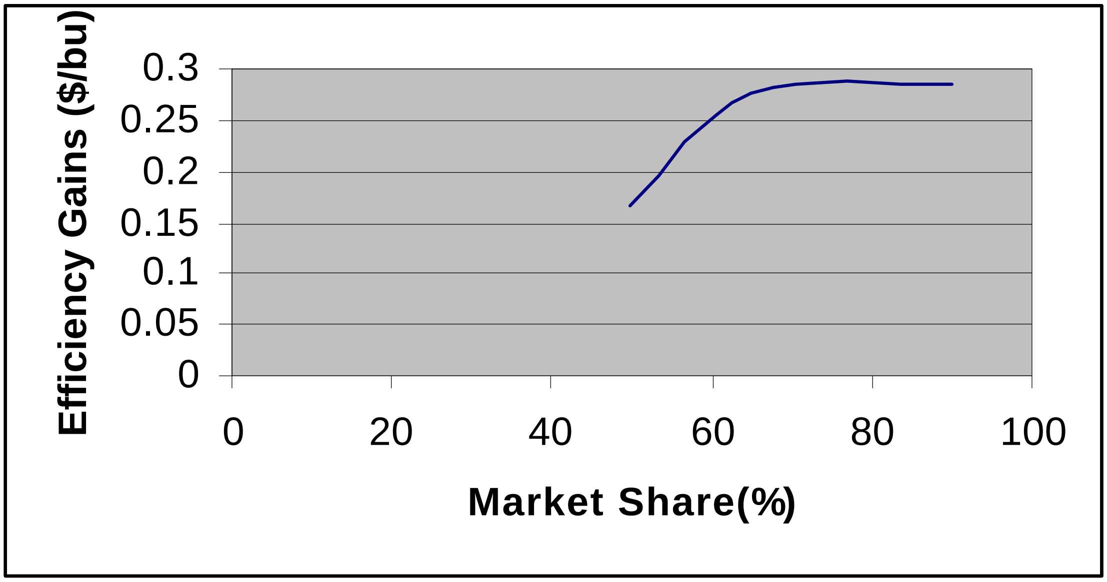
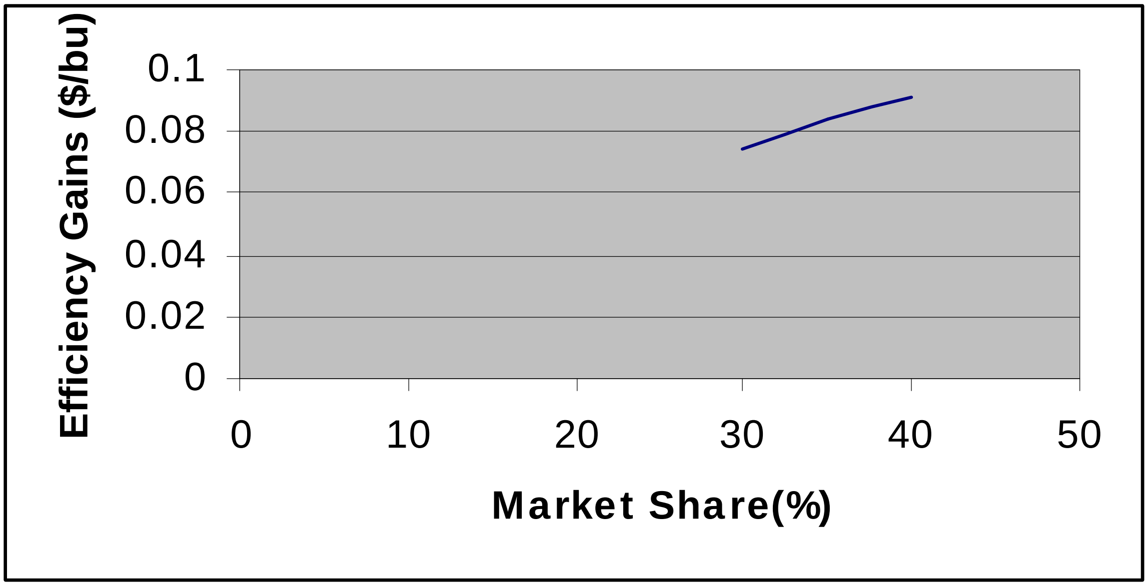


Figure 3. Estimated Efficiency Gains Versus Pool's Market Share for Durum Wheat



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

1. In 1999, government emergency and disaster payments for North Dakota was about $850 million (NDASS, 1999). Total disaster and insurance payments were $1.2 billion for about 31,000 farmers. Declining price trends might affect long-run global competitiveness of U.S. growers because other major wheat producing nations and regions like Australia and the European Union have been experiencing increases in wheat exports (NASS, 1998).

2. Although ND produces 85% and 50% of total U.S. durum and HRS wheat, the U.S. 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 U.S. a pool may operate more effectively with Canadian participation since the volume managed by the pool maybe crucial for its survival.

3. A potential structure for the pool if created, will be like a cooperative. This will legally protect the pool from antitrust-monopolistic liabilities. An example of such a structure is the California Rice Pool. Vercammen, Fulton, and Hyde (1996) developed a nonlinear pricing schemes for agricultural cooperatives that can be used as incentives to attract members. A nonlinear marketing cost scheme will be used in this study to provide incentives for pool members.

4.The price elasticities of supply for durum wheat are 0.86 in ND and 0.98 for other regions in the U.S. The elasticity for spring wheat is 0.03 for ND and the rest of the U.S. Therefore, if prices for durum increase, supply may increase proportionately to the benefit of free riders.

5. There are very few grain companies(ADM, ConAgra, Cargill, among others) with the majority of the market share. Also, the participation of these companies in the US domestic market and the world market creates imperfect competition in the grain merchandising and processing industry.

6. 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 for the pool.

7. Although farmers receive low and high prices for low and high quality grain, there have been several grain blending studies (Fulton and Hucq, 1996; and Johnson and Nganje, 1999) that have analyzed the benefits of blending. In some instances grain handlers and merchandisers buy low quality grains for a discount and blend them with high quality grains that meet acceptable quality specifications and sell for prevailing market prices.

8. 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. Given the volume of grain the pool will handle and its marketing expertise it will be adept to blend off low quality grains and return a premium to its members.

9. 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. The net margin for grain cleaning (SIC code 0723) ranged from 1.8 to 13.5 cents per bushel. Second, personal communication with industry officials 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 U.S. 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 (1999) were used to estimate a range of 1.5 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.

10. North Dakota produces about 85 percent of the durum wheat and 50 percent of the hard red spring wheat produced in the United States. North Dakota's market share for durum wheat is about 60 percent and 40 percent for HRS of U.S. consumption. The United State imports about 24 million bushels of durum wheat and 45 million bushels of HRS from Canada annually.

11. The difference between the Present Value with cooperation and without cooperation is $2ä^T[-1 + ä/(1-ä)]$. This is positive if the discount rate (ä) < 0.5.

12. $EU(PS_i) \geq EU(DEV)$ <=>

$$ä_i \geq \frac{ui(\hat{\tilde{o}}_i,\ ó^*_{-i}) - ui(ó^*)}{ui(\hat{\tilde{o}}_i, ó^*_{-i}) - ui(\bar{\tilde{o}})}$$

In this particular game the three solution concepts reveal that cooperating to form a wheat pool is the best strategy. This implies that the right-hand side is zero. Since the discount rate will always be greater than zero, efficiency gains from pooling may be significant to sustain the pool.