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Todd Preszler, William Wilson,
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This paper uses game theory to characterize strategies of bidders in international wheat transactions. Simulations show that the seller's share of total surplus decreases as the number of bidders increases. Bidders with higher quality information have a strategic advantage, which is reflected in higher expected payoffs in bidding games.

1. Introduction

Participants in grain trading businesses are constantly involved in "bidding games" in which competitors bid to supply grain to a buyer under specific terms. If information among competitors is asymmetric, the complexity of bidding games increases. Asymmetric information arises when one player has private information others do not possess. This is a common feature of bidding situations grain traders confront.[1] This paper analyzes impacts of asymmetric information that result from dichotomous pricing mechanisms that exist in international wheat transactions and are also evident in other market situations. This problem can be viewed by using game theory models of competitive bidding. Of particular importance is the distribution of expectations about competitor bids.

Traditionally, competitive market mechanisms result in only a small degree of private information. However, during the past decade with growth in market intervention mechanisms (e.g., EEP) and intercountry competition among private grain trading firms and single seller agencies, issues related to asymmetry of information have

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*Graduate student, professor, and assistant professor, Department of Agricultural Economics, North Dakota State University, Fargo. Selected paper presented at the 1992 AAEA Annual Meeting, Baltimore, MD.

[1]Caves suggested that economies of information is a key feature explaining conduct in the international grain trading industry.

become more important. Issues pertaining to bidding competition and information have been referred to as the "price transparency problem." In particular, exporting countries with single-seller agencies do not reveal prices or other terms of trade (e.g., qualities, credit terms, or, for that matter, actual sales). This contrasts with highly competitive public transaction mechanisms in the United States (and to some extent, the EC) in which virtually all terms of trade are revealed. Allegations have been made that this gives an important strategic advantage to countries with single-seller agencies.[2] Countries with single-seller agencies defend their existence on the ability to perform transactions with greater confidentiality than would be possible under a more competitive environment.[3]

We develop a framework to analyze these issues. Since actual transaction data cannot be used, we use hypothetical data (based on industry discussions) that typify the problem. We show crucial relationships that emerge from competitive bidding, and impacts of information and the number of bidders on game outcomes. We also identify and interpret informational asymmetries as an important source of strategic advantage.

2. Game Theory Competitive Bidding Models

This section develops a game theory model of competitive bidding to analyze export tenders.[4] Essential elements of a game are players, actions, information, strategies, payoffs, outcomes, and equilibrium. Players, actions, and outcomes are

[2]See in particular a United States Government Accounting Office study (pp. 23-24).

[3]This problem is also important among traders within a country. In fact, numerous trading practices and institutions have emerged (e.g., confidential rail contracts, tapered vertical integration in the market system, increasingly specific quality terms in contracts, etc.), which appear to increase the degree of asymmetry in information.

[4]Competitive bidding games are discussed in McAffee and MacMillan, Wilson, Reece, Milgrom, Capen et al., and in texts by Rasmusen and Fudenberg and Tirole.

referred to collectively as game rules. This game is a first-price, sealed-bid auction among grain exporters.[5] The importer tenders to buy a certain quantity (i.e., one metric ton) of grain with specific terms of trade (type, quality, location), requesting offers from two or more exporters. Traders evaluate their positions and opportunities to formulate a bid. The trader with the lowest bid wins the auction and receives the amount of his/her bid. Losing traders receive and pay nothing.

Players are traders for exporting firms or agencies. Each player chooses a bid to maximize expected profit. Nonplayers are the importer and nature. The importer serves as the auctioneer. Nature takes random actions at specific points in the game with specified probabilities. Players' actions are modeled endogenously, while nature's actions are exogenous.

Nature reflects beliefs about the players' probability distribution of "costs" of delivering grain. Specifically, distributions reflect players' beliefs about each other's cost of executing a contract.[6] In this model, costs are assumed to have a normal distribution. The expected value and standard deviation of costs are denoted μ_i and σ_i, respectively, for the ith player. In our base case, all players have a mean cost of \$158 with a standard deviation of \$1, and all players share a knowledge of these parameters.

Mean cost for player i (μ_i) is the greater of the expected cost of acquiring or assembling grain in deliverable position and the expected sale price to the next best

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[5]A first-price, sealed-bid auction is an efficient pricing mechanism and is equivalent to a Dutch auction (see Milgrom for discussion). In both cases, goods are allocated to the lowest bidder at a price equal to the bid. These have the same "reduced normal form" and, therefore, lead to identical strategies and outcomes. In an English auction, the bidder with the lowest value receives the sale, but only at the second lowest price.

[6]These would include costs of acquiring and transporting grain and, in addition, any opportunity costs associated with foregone sales to other markets.

alternative. Thus, it represents the grain's expected opportunity cost. Standard deviation is a measure of the "quality" of information. In this game, each player moves once. Strategies available to the players are a continuous set of bids (b_i), expressed as a multiple (s_i) of the player's cost, c_i. Thus, player i's bid is $b_i = s_i * c_i$.

By assumption, players commit themselves to a strategy s_i *before* Nature makes its move--that is, before the cost c_i becomes known to player i. However, bids (the product of s_i and c_i for player i) are made *after* Nature moves. Because bids are a preselected multiple of costs (which are unobserved by opponents), they are effectively random.

Player i seeks to maximize expected payoff:

$$E\,\pi_i = E\;(b_i - c_i)\cdot PW(b_i)$$

where (b_i - c_i) represents the payoff from a winning bid and PW(b_i) denotes the probability of winning. By virtue of our assumptions about costs and "preselection" of strategies, opponent's bids are normally distributed. Let b_{-i} denote the bid of an arbitrary opponent, and let μb_{-i} and σb_{-i} denote (respectively) the mean and standard deviation of that bid. If there are n players whose costs are distributed independently, the probability that player i will win is given by

$$PW(b_i) = \prod_{-i=1}^{n-1}\left[1-\int_{-\infty}^{b_i}\frac{1}{\sqrt{2\pi}\;\sigma b_{-i}}e^{-(1/2)\,[(b_i-\mu b_{-i})/\sigma b_{-i}]^2}db_i\right] \quad \textit{where } -i \neq i.$$

Thus, the probability of underbidding n-1 opponents is the product of the probabilities of underbidding each individually.

The expected payoff for player i is (implicitly) a function of all players' strategies. Let s_{-i} represent a vector of opponents' strategies; taking these as given, the "best response" for player i is the strategy s^*_i satisfying

$$E\ \pi(s_i^*, s_{-i}) \geq E\ \pi(s_i, s_{-i}) \quad \forall s_i \neq s_i^*$$

When all players adopt "best responses" to their opponents' strategies (and players' expectations are mutually consistent), a Nash equilibrium is attained. In a Nash equilibrium, no player has an incentive to deviate from his/her chosen strategy. For purposes of the following simulations, Nash solutions were identified through a numerical search procedure.

3. Simulation Results With Symmetric Information and Cost Distributions

Case 1 reflects a bidding environment with symmetric information and cost distributions. Specifically, all players observe bids from previous and nearly concurrent transactions and use this information to construct beliefs for the current auction. This information structure leads to low standard deviations of competitors' costs.

Figure 1 shows response functions for a two-player game under Case 1 beliefs. Each curve represents a player's best response to his competitor's strategy. The intersection of best-response curves for Players 1 and 2 represents a Nash equilibrium for the two-player game. In evaluating alternative bidding strategies, player 1 recognizes that if he bids exactly his mean cost, player 2's best response is to bid 1.0047. Recognizing player 2's strategy, player 1's best response is to bid 1.0065. This process continues until neither player can improve his payoff by deviating from his strategy.

Table 1 shows outcomes of three simulations played under these beliefs. Since players have the same mean costs and standard deviations, outcomes are the same and are presented only once. Players' best responses are to bid 1.008 times their mean costs, yielding a payoff of $1.26 if the bidder wins the auction. The probability of winning is .50 for each player with this bid; thus, the expected payoff is $0.63.

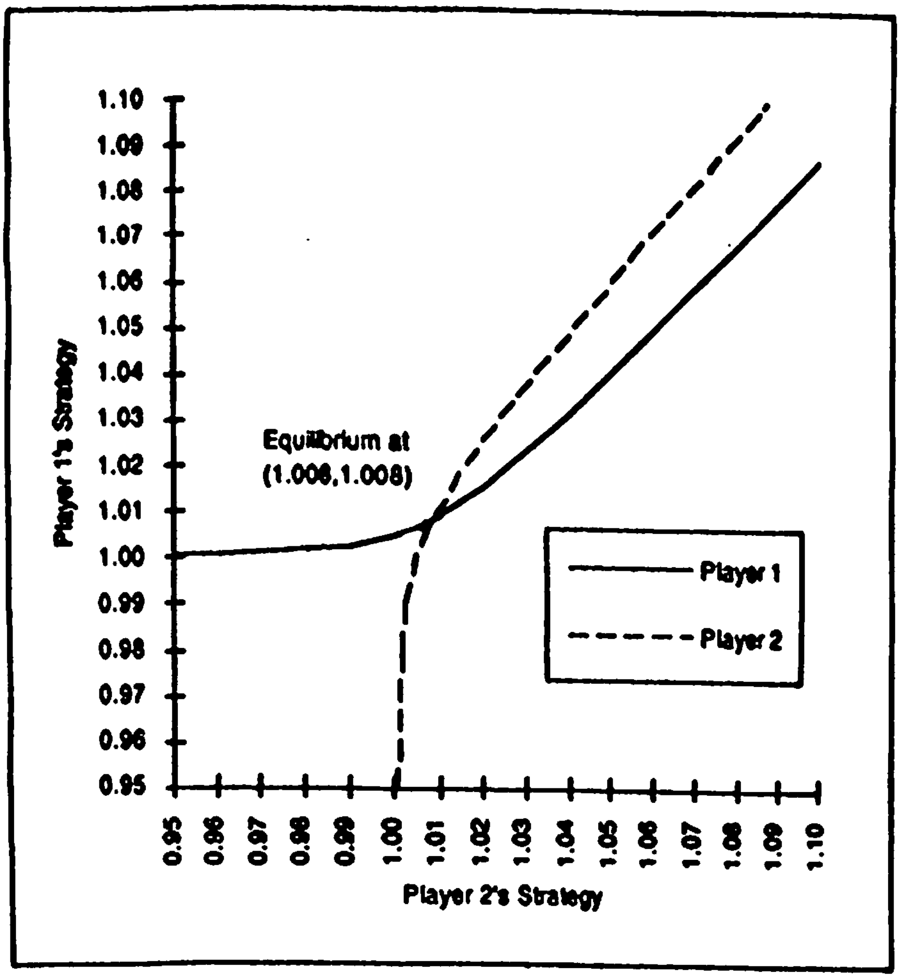

Figure 1: Response Functions of a Two-Player Bidding Game

The next two simulations show how n (the number of bidders) affects equilibrium outcomes. As n increases, players bid more aggressively and have lower probabilities of winning and lower expected payoffs. From a welfare perspective, this demonstrates that grain buyers have a clear incentive to attract as many bids as possible.

4. Simulation Results With Asymmetric Information

In these models, we simulate impacts of asymmetric information on a first-price sealed-bid auction. The problem includes several bidders--two of whom have the same costs and standard deviations as in the previous case. The third bidder is an exporter representing a competitor country with a single-seller agency (e.g., Canada, Australia). An important characteristic of this competitor is the standard deviation of its opportunity cost. This is greater because information either is not released about transaction prices or is only released selectively. In addition, information about sales and commitments to alternative markets (representing opportunity values) are masked.

In this example, we allow one competitor with these characteristics. For illustration, suppose that two U.S. companies, U_1 and U_2, are bidding against Canada, C_0, for sales free-on-board at Pacific Northwest ports (FOB PNW) to a non-EEP customer. This analysis applies a one-shot bidding game, and longer term sales strategies, target marketing, etc. do not affect bidding or the game's outcome.

Table 2 shows outcomes under these assumptions. Comparing this outcome with the three-player Case 1 simulation, we observe that all players bid less aggressively and have higher payoffs from winning and greater expected payoffs. C_0 has a strategic advantage due to information asymmetry, which is manifested in values for both $PW(b_i^*)$ and $E\pi_i$. These effects are directly attributable to the increased uncertainty about C_0's opportunity cost.

The thought process causing U_1 and U_2 to increase their bids from the base case runs as follows: C_0's bid is more likely to be higher or lower than U_1's and U_2's (i.e., higher σ). If it is higher, U_1 and U_2 benefit from increasing their bids. If it is lower, U_1 and U_2 can reduce their bids to increase their probability of winning. However, if C_0's bid is below U_1's and U_2's opportunity costs, they cannot have a profitable win. Thus, they "chase" the possibility of higher bids, but not lower bids. C_0, having better information, finds it optimal to lower its bid. This decreases its payoff if it wins but increases its probability of winning sufficiently to give it a higher expected payoff than for U_1 and U_2. Given a constant total surplus, exporters capture a higher percentage of total surplus in a market with asymmetric information (comparing Case 1 and 2); thus, the importer loses consumer surplus.

In Case 3, we provide results of a bidding game similar to Case 2 but include four bidders: two with refined information and two with greater informational uncertainties. This can be taken to represent a situation where bidders from the United States (US), EC, Australia (A), and Canada (C) compete, and the latter two are less transparent (more refined information). This would be typical of a C&F sale to an EEP customer. Greater uncertainties result from 1) incurring greater risks associated with international logistics and 2) the process of simultaneously bidding on EEP and determining of accepted bonuses. The combination of these is reflected in σ, which is greater for all players. Another feature of Case 3 is that EEP increases σ about the U.S. offer when viewed from competitor countries. In this paper, the effect of EEP and restitution values (themselves being determined through bidding) are summarized in the price. For comparison, we continue to use the same price level as Case 1 and only alter σ.

Table 3 shows outcomes under this information structure. Case 3 outcomes show the same effects of increased standard deviations between models (Case 1 with 4 players and Case 3) and standard deviation differences between players that were described in Case 2. An important point is the greater shift in total surplus (relative to the base case) in Case 3. Winning probabilities and expected payoffs are the same for U.S. and EC traders and, similarly, are the same for Australia and Canada. The only difference between the former and latter two traders is the standard deviation of costs. The expected payoff to traders in the symmetric case (\$.05) is substantially less than in this asymmetric case ($.21 and $.23). These results illustrate the combined impacts of the informational advantages of single-seller agencies and increased uncertainty for all bidders.

4. Conclusion and Discussion

Game theory provides a methodology to study behavior of players in noncooperative, adversarial situations. This paper uses game theory to characterize strategies of bidders competing via tenders in international wheat transactions. Our simulations show that the buyer's (seller's) share of total surplus increases (decreases) as the number of bidders increases. We show that the buyer's (seller's) total surplus decreases (increases) as the information asymmetry increases, i.e., bidders bid higher to seek compensation for the riskier environment. Bidders with higher quality information have a strategic advantage, which is reflected in higher expected payoffs in bidding games.

The framework and results used in this study provide an interpretation of the "price transparency problem," which is receiving increased attention. Price transparency and lack of transparency are viewed as attributes of different national marketing systems. However, transparency is a matter of degree: a market system is "more transparent" to the extent that it reveals more information relevant to the formulation of competitive bids. Single-seller agencies (i.e., in Canada and Australia) reveal few details of their transactions. In the U.S. marketing system, many terms of trade are revealed, and sufficient information is available (e.g., futures prices, basis levels, and announced EEP subsidies) to permit refined estimates of transaction prices. This information asymmetry--represented by the distribution of costs in our model--constitutes a disadvantage for firms operating in a more transparent competitive environment.

Table 1: Simulation Results With Symmetric Information and Cost Distributions

Element	Number of Players: Two	Three	Four
μ_i	158	158	158
σ_i	1	1	1
Equilibrium s_i^*	1.0080	1.003982	1.002651
Equilibrium b_i^*	159.26	158.63	158.42
Winning π_i	1.26	.63	.42
$PW(b_i^*)$	.50	.25	.125
$E\pi_i$	.63	.16	.05

Table 2: Simulation Results With Asymmetric Information and Cost Distributions

Element	Players: U_1	U_2	C_0
μ_i	158	158	158
σ_i	1	1	5
Equilibrium s_i^*	1.006606	1.006606	1.004966
Equilibrium b_i^*	159.04	159.04	158.78
Winning π_i	1.04	1.04	.78
$PW(b_i^*)$	.24	.24	.36
$E\pi_i$	.25	.25	.28

Table 3: Import Tender Results With Four Exporters With Asymmetric Information and Cost Distributions

Element	Players: US	EC	A	C
μ_i	158	158	158	158
σ_i	2.5	2.5	7	7
Equilibrium s_i^*	1.011504	1.011504	1.009341	1.009341
Equilibrium b_i^*	159.82	159.82	159.48	159.48
Winning π_i	1.82	1.82	1.48	1.48
$PW(b_i^*)$	.12	.12	.15	.15
$E\pi_i$	.21	.21	.23	.23

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