Agricultural Economics Report No. 376 May 1997

Bidding on Railcars for Grain: A Strategic Analysis

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Acknowledgments

Appreciation is extended to Demcey Johnson, Frank Dooley, Denver Tolliver, and Wesley Wilson on earlier versions. Charlene Lucken provided editorial assistance and Carol Jensen prepared the document. However, errors and omissions remain the responsibility of the author.

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Abstract

Many of the U.S. railroads have introduced highly differentiated services for grain shipments in recent years, generally in the area of forward guaranteed car service. Taken together with other alternatives, these mechanisms have had the effect of establishing priority allocations among shippers. In most cases, pricing and allocation of these services has been with some type of bidding mechanisms. This paper explores the economic implications of these mechanisms on the grain shipping industry. A model was developed to identify factors affecting the value of these services and was analyzed in the context of a typical midwestern grain shipment. A game theory model of competitive bidding was also developed to analyze the effects of critical strategic variables on equilibrium outcomes.

Key Words: railcars, guaranteed car service, railcar allocation, options, guarantee, bidding models, valuation

Bidding on Railcars for Grain: A Strategic Analysis

William W. Wilson, Bruce L. Dahl[*]

Due in part to deregulation since the Staggers Rail Act of 1980, U.S. railroads have introduced various pricing innovations during the past decade. In early years, these were unit train discounts and confidential contracts. Since the late 1980s, of particular importance has been the advent of railcar offerings up to 5-6 months forward for guaranteed car placements. Taken together, the combination of alternatives has the effect of ascribing priorities among shippers. While these dimensions of service and pricing are common in many other service industries (e.g., airlines, hotels, restaurants), programs entailing forward guarantees in grain shipping are innovative and have had important implications for the conduct of firms in the grain marketing industries. In addition, their legality was challenged, but the Interstate Commerce Commission (ICC) ultimately ruled in their favor and, in fact, encouraged other railroads to consider these mechanisms for solving car allocation problems.

Before the late 1980s, the predominant form of railcar allocation to grain shippers was some form of *first-order-first-serve process* as defined in railroad tariffs. Cancellation penalties were not used, resulting in *phantom orders*, thereby causing uncertainty in making rail operations and capacity decisions. The Burlington Northern Railroad (BN) was the innovator in this pricing mechanism with the introduction of its COT (Certificate of Transport) program in 1988. Important features of that program include forward car offerings to shippers for a portion of their fleet, prepayment fees used as cancellation penalties, and guarantees provided by the BN for prescribed delivery windows. Cars are allocated among shippers using an auction process, and transferable certificates are issued. The COT program has had the effect of establishing priorities among shippers for the allocation of railcars.[1] Generally, shippers opposed allocation of railcars using price and "preferred that all service be allocated via a non-price method during shortage periods" (ICC, p. 458).[2] In an industry where notions of equitable distribution and common carriage were somewhat nebulous in the post-Staggers period, these innovations were challenged by shippers under the Interstate Commerce Act. Ultimately, the ICC decided in favor of the BN, indicating that "allocation by price is efficient because service is provided to those who value it most" (ICC p. 459) and that COTs should "enhance long-run efficiency by giving incentives to maintain an optimally sized grain car fleet."

Since that decision, many other railroads have introduced similar mechanisms. The CP/Soo introduced the PERX program in its wheat lines. The Union Pacific (UP) had previously adopted its ACOS system (Advanced Car Order System) under which a portion of cars were allocated based on historical shipments. This was subsequently replaced with a comprehensive car allocation system, including "Vouchers" for guaranteed forward shipments.

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[1] See Priewe and Wilson (1997b) for a detailed description of these mechanisms.

[2] Problems related to car allocation and railcar shortages are not new and have been discussed in Apogee; Baumel and Kober; Baumel and VanDerCamp; Gelston and Greene; Moser; Niedens; J. Norton; Pautch, Lapan, and Baumel; Pedraza; and W. Wilson.

Similar mechanisms have also been introduced by the Illinois Central. Allocation of each of these is through bidding among shippers. Canadian railroads are experiencing similar problems in the post-WGTA period. Under the previous regulatory scheme, cars were allocated through the Grain Transport Authority (an industry/committee process), using a labyrinth of rules, and were based on historical shipments. This was abandoned in 1996 and replaced by another industry consensus group, CAPG (Car Allocation Policy Group) using similar procedures, until a longer-term strategy is agreed upon.

This evolution has important implications for both carriers and shippers. To adopt these mechanisms, railroads must make critical decisions about the mechanism design which ultimately affects the structure of bidding competition. In addition, combined with car allocation mechanisms for other service categories (e.g., SWAPS, GEEPS, Pool Cars, etc., as well as the mechanism for distribution of general tariff cars),[3] these comprise a system of service options each railway offers shippers. Ultimately, an important element of competition among carriers is captured in these service options. For shippers, efficient use of these mechanisms requires greater integration between grain merchandising and logistics to exploit these efficiencies.[4] Shippers also must assess effects of critical variables to develop strategies for bidding on rail cars.

Bidding competition is not alien to the grain marketing industry. Two important functions provided through bidding processes are pricing and allocation. Transaction prices are established through bidding, and allocations are made among market participants. Auctions are particularly appealing when there are informational asymmetries between the seller and potential bidders. Because of the efficiency of bidding competition in fulfilling these roles, it is used in numerous commodities, products, and services in the agricultural marketing system.

There is extensive literature in general economics on the appeal of auctioning mechanisms. Cassady provides a historical overview of auction strategies and mechanisms. Several bibliographies [McAfee and McMillan (1986, 1987, 1996b); Engelbrecht-Wiggans; Milgrom (1985, 1987, 1989); Rothkopf and Harstad; Milgrom and Weber; Riley and Samuelson; Vickery; R. Wilson (1992)] review the literature on auctions and bidding strategies. Texts (including Monroe, Nagle and Holden, Lilien and Kotler, Rasmussen, and Kottas and Khumawata) provide some practical motivations for auctions and analytical approaches to bidding strategies. Game theory concepts have been used to design competitive bidding mechanisms for auctioning numerous items and services, including OCS oil leases (Reece) to spectrum licenses (R. Norton, McAfee and McMillan 1996a), electric power and industrial chemicals (Chao and Wilson 1995), and airwaves (Crampton, *The Economist*). Without the use of auctions, other forms of pricing (e.g., negotiation, posted prices) and allocation would have to be used.

There are several important questions about the execution of bidding programs in the case of rail auctions of forward guaranteed freight. Of particular interest are 1) the effect of the

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[3] See Priewe and Wilson (1997b) for a description.

[4] See Priewe and Wilson (1997a) for an analysis of alternative strategies.

number of bidders on bidding competition, 2) identification of competitors' bidding strategies, 3) determination of optimal bids, and 4) how information revealed to bidders affects bidding competition. These questions are frequently raised by market participants and have not been addressed in the agricultural economics literature.

This paper analyzed the strategic implications of forward railcar auctions. The first section discusses relevant concepts of efficiency. The second section develops an analytical model to demonstrate the effect of critical variables on the value of forward car guarantees. The third section develops a strategic model of bidding and applies it to the railcar problem. Effects of critical variables affecting equilibrium strategies are demonstrated. The final section provides a summary and implications for both shippers and carriers.

Efficiency and Railcar Allocation Mechanisms

We focus on two forms of efficiency: distributional and pricing.

Distributional Efficiency[5]

In the context of pricing unstorable services (e.g., electric power or transport), efficiency requires that service is deferred for those customers who would incur the least cost. Thus, an efficient rationing (allocation) is one in which the resource is allocated according to customer valuation. Simply put, an allocation is efficient if the order of service corresponds with the value of the service across customers.[6] In the case of railcar allocation among grain shippers, an efficient allocation would be one in which those with the greatest value would receive cars first. For example, a shipper with an export commitment in which a large demurrage cost would be incurred if the shipment is received late should receive priority in car allocation relative to one simply shipping from one storage facility to another for storage. Allocation would be inefficient if the latter received cars before the former. If their values are sufficiently different, arbitrage could occur with the latter selling to the former and profiting due to their differences.

Priority pricing schemes are being increasingly used to more rationally serve competing demands with fixed capacity (R. Wilson, 1993, pp. 236-258). Priority pricing improves efficiency by serving customers in the order that conforms with the cost (implicit or direct) incurred from the shortage or deferral, *vis-a-vis* random rationing, and is being implemented in numerous applications from public utilities (Pricing Strategy Associates) to the internet. Previous research has shown that priority service pricing is superior to random rationing on efficiency grounds (R. Wilson, 1993). It is highly unlikely that allocation using historical

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[5] This form of efficiency was referred to by the Interstate Commerce Commission in reference to Kalt's expert witness testimony.

[6] For example, in power generation, the value of uninterrupted service for a hospital is greater than residential air conditioning or agricultural irrigation. Thus, during periods of excess demand, it would be efficient to interrupt service to the latter two-market segments first. Random rationing would impose greater costs on the former. See R. Wilson 1993 (Chapter 10) for complete development of the priority pricing problem.

shipments would be efficient. The only way historical allocation would be efficient would be if the same shippers had a high value of guaranteed service continually through time.

One of the benefits of priority pricing is purely informational. By having different prices associated with different service priorities, information on the value of capacity increments that improve reliability is derived. This indicates shipper willingness to pay for capacity increments that are unavailable in undifferentiated services. Given the signals generated in a priority pricing mechanism, railroads can improve capacity and operating decisions which influence car-placement timeliness.

Pricing Efficiency

In grain transportation, it is important to devise a mechanism for setting priorities due to the volatility in demand and car shortages and surpluses. Car allocation problems are also compounded by inversions in the commodities market and, in some cases, is exacerbated because of ordering and allocation procedures. In each case, the railroad is fraught with allocation decisions and how to establish priorities. Transmission of signals regarding the value of marginal capacity or improved operating efficiency to railroad management has been limited.

Pricing plays two important roles in car allocation. One is to induce shipper self-selection. By offering alternatives regarding guarantees, forward car ordering, priority allocation, and rates, shippers would choose the option that yields them the greatest payoffs (or minimizes their expected total cost). Without alternatives, shippers would be forced to accept allocations which may not be best from their perspective.

The second role is to design a mechanism so information about the value of guaranteed services is received by the carrier. This can be achieved either through some form of bidding competition or through innovations in tariffs. At the extreme, rates could be determined on a "spot" basis and change whenever there was a change in market fundamentals (i.e., reflected in equation 1.5 below). Using bidding competition, this would assure that shippers with the greatest demand for priority would receive cars which would result in a superior allocation relative to any form of random rationing or use of historical averages.

Spot rates, which are revised continuously, would result in immense uncertainty for shippers and carriers. Furthermore, the disadvantage of spot pricing is that the railroad would not receive information which could be used to make future capacity adjustments. The alternative is some form of a forward contracting or bidding mechanism. Signals transmitted in forward bids for shipping services could be used to improve allocation decisions, whereas a spot market is merely a rationing mechanism.

Factors Determining the *Value* of Guaranteed (Forward) Car Service (GFCS)

It is important to understand the sources of value and the logic of the market functions and interrelationships which give rise to GFCS's having value.[7] In this section, we provide a simple model to identify the value of GFCSs to shippers. The value of GFCSs to shippers involves a myriad of factors, each of which has an impact on shippers' profits. First, we describe the setting under which shippers (grain merchandisers) make decisions, outlining the various options of the decision. Then we frame the decisions, identifying the payoffs associated with different decisions. Finally, we illustrate the process and comparative statics using data from the Northern Plains to the Pacific Northwest ports.

Model Formulation

There are two important features of a GFCS from a grain merchandising perspective. First, it provides a mechanism to lock in rates and, therefore, shipping costs and margins, for a particular movement. Second is that guarantees are provided for car supply. As a result, risks associated with transport are reduced. GFCS has value primarily due to these features. Because fundamental factors determining value vary, the value of GFCS varies through time and potentially across shippers.

A general model is developed to demonstrate the impact of factors which influence GFCS values. A payoff function of a merchandiser for an individual transaction is the basic analytical tool.[8] To illustrate decisions associated with GFCS, we develop a simple model to explain payoffs associated with alternatives. In this model, all shipments are assumed to occur one period forward, i.e., in time t+1, and the unit of time in all calculations is one-half month to coincide with industry practices using First-Half/Last-Half shipping windows for each month. If shippers do not receive cars on the *want date*, it is assumed they will be received 1 period (15 days) later and would incur additional storage and interest costs. Demurrage costs are incurred if cars are not received on the want date. Finally, we assume there are no alternative markets or modes.[9] Thus, if cars are not received, the only alternative is additional storage cost.[10]

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[7] Priewe and Wilson (1997a) develop a stochastic simulation model of a shipper to analyze the risks and payoffs associated with this and other shipping mechanisms.

[8] This approach is potentially limiting since we are analyzing payoffs of individual transactions. In practice, shippers with multi-plant operations (or management agreements) have advantages in using these instruments. This is due primarily to uncertainty in shipping demand for an individual shipping station and the ability of shifting origins. These features of the analysis could be incorporated here, but the results would be complicated.

[9] Wilson (1989) demonstrates a more general formulation including alternative markets and modes. In that case, the conditions under which premiums could be negative are illustrated. Here, the distinction is not important, and therefore the more simplified formulation is presented.

[10] This is simplifying only.

Following are definitions used in the model:

π^g	trader's margin on a GFCS (guaranteed) transaction
π^N	trader's margin on a transaction, without a guarantee
P_j^{t+k}	commodity price at the destination market j, and t+k indicates k time periods forward
P_i^t	commodity price at origin i at time t
T_{ij}	tariff rate fore shipping from i to j using a traditional allocation mechanism
T_{ij}^g	price (value) of a GFCS
r	interest cost
S	storage (physical) cost
D	cost of demurrage
R_1	probability of receiving cars on the want date, t, and $(1-R_1)$ is the probability of receiving cars during the next period

Payoff functions for individual decision makers are defined first using a GFCS and then for a non-GFCS shipping position.

The payoff for a transaction using a GFCS is

$$1.1) \quad \pi^g = P_j^{t+1} - P_i^t - T_{ij}^g - r$$

Manipulation yields the following which indicates the value of T_{ij}^g:

$$1.2) \quad T_{ij}^g = P_j^{t+1} - P_i^t - r - \pi^g$$

For a non-GFCS transaction, or market in which a GFCS does not exist, the equivalent payoff function includes the risk of not receiving cars $(1-R_1)$. This payoff function includes a margin if cars are not received on their want date, implying they are received during the next period. The payoff function is

$$1.3) \quad \pi^N = R_1(P_j^{t+1} - P_i^t - T_{ij} - r) + (1-R_1) \cdot (P_j^{t+2} - P_i^t - T_{ij} - 2r - S - D]$$

Manipulation yields the following expected payoff for a transaction in which GFCS does not exist, or is not used:

$$1.4) \quad \hat{T}_{ij} = (1-R_1)(P_j^{t+2} - S - D) + R_1 \cdot P_j^{t+1} - r(2-R) - \pi^N$$

The value of a GFCS can be defined as $T_{ij}^g - \hat{T}_{ij}$. Rearranging and combining equations, the value of a GCS can be defined as:

$$1.5) \quad T_{ij}^g - \hat{T}_{ij} = (1-R_1)[(P_j^{t+1} - P_j^{t+2}) + (r + S + D) + (\pi^N - \pi^g)]$$

These results indicate that the value of GFCS increases with 1) increases in the probability of not receiving cars on the want date $(1-R_1)$; 2) increases in the price spread, $(P_j^{t+1}-P_j^{t+2})$; 3) increases in time-dependent storage costs (r + S + D); and 4) increases with the margin differential, ($\pi^N - \pi^g$), if applicable between non-guaranteed and guaranteed transactions.

Implications

Factors influencing the value of GFCS include intermonth price spreads in the commodity market, costs associated with not receiving cars (additional storage and interest and demurrage), and the probability of timely car placement under traditional (or alternative) allocation mechanisms. Values of GFCS are determined by these factors.

<u>Demand for GFCS.</u> There are two sources of demand for GFCS. One of these is the *speculative demand.* Demand may exist for GFCS if rates for tariff movements are expected to increase.[11] This may be interpreted by rearranging equation 1.5.

$$1.6) \qquad T_{ij}^{g} = \hat{T}_{ij} + (1-R_1)[(P_j^{t+1} - P_j^{t+2}) + (r + S + D) + (\pi^N - \pi^g)]$$

If traders expect increases in rates for tariff movements, the value of GFCS would increase as a means for protection. This is an important feature in the evolution of COTs and PERX. Under the Staggers Rail Act, there can be increases in tariffs of these underlying movements with a 20-day notice, a period shorter than the duration of most contracts.

Hedging demand comprises the other element of demand for GFCS and refers to the service protection it confers to shippers. These are related to the factors included in equation 1.5. Most important is the probability of not receiving cars on the want date relative to the commodity market inversion (in part due to the Export Enhancement Program, EEP),[12] giving premiums for guaranteed nearby shipment.

<u>Shipping Versus Storage Demand</u>. An important element determining the temporal demand for shipping is the demand for storage. Shippers evaluate alternative returns associated with shipping during different periods. Factors determining these returns are the intermonth price spread in the commodity market, storage costs and shipping rates. In a normal commodity market, positive price spreads exist between consecutive shipping months. These are typically large enough relative to storage costs to provide an incentive to store the commodity between months. Negative intermonth price differentials exist in inverted markets. In an inverted market (reflecting some type of shortage situation in the nearby months relative to the deferred), shippers would have a positive value for guaranteed cars for nearby shipments. Of course, the extent that the premium for transport (shipping costs) increases for nearby shipments, the shipper's return would be reduced, potentially to the point of indifference between shipping months. This is an important feature of GFCS because it has the effect of evening out the inter-temporal demand for shipping (See Priewe and Wilson, 1997a).

There has been substantial variability in the premium both through time and across shippers (see Priewe and Wilson, 1997b). The model used here demonstrates numerous reasons

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[11] See Priewe and Wilson (1997a) for a procedure to determine the probability that tariff rates would increase.

[12] In the COTs case, the ICC recognized that part of the reasons for the market inversions during the late 1980s was due to the administration of the EEP program which generally was for subsidized sales in more nearby shipping periods, relative to deferred.

to expect the value for GFCS to vary both through time and across shippers. It is expected that the intermonth price spread and storage and interest costs would be nearly identical across shippers. However, the value of potential demurrage costs and individual shippers' expectations of timely receipt of cars (R_1) vary across shippers. This is no doubt the case in the United States and is what has caused shippers to have different bids (and therefore values) for guaranteed transport.

Comparative Statics

To demonstrate the influence of these variables on the value of a GFCS, representative data were assembled for wheat shipments from the Northern Plains to the Pacific Northwest ports. These are used to define the base case from which critical variables are varied to demonstrate their effect on the value of GFCS. Table 1.1 lists values used in the base case. Values for R_1 are hypothetical. All other values are intended to reflect conditions in the early 1990s.

Table 1.1. Base Case Variable to Illustrate Values of GFCS

	cents/bushel
PNW FOB	
Nov 2nd half $(P^{t+1})_j$ *c/b*	591
Dec 1st half $(P^{t+2})_j$ *c/b*	594
Origin	490
Shipping and Handling Costs	
Tariff (T_{ij}) *c/b*	100
Handling Tariffs *c/b*	8
Margins ($\pi^G = \pi^N$) *c/b*	2
Ship Demurrage (D)[13] *c/b*	12.25
Storage Costs	
Storage *c/b/month*	3
Storage *c/b/15 days*	1.5
Interest *c/15 days*	1.43
Rail Cars	
Prob. of Receiving Cars (R_1)	.7
Prob. of not Receiving Cars ($1-R_1$)	.3

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[13] Based on $15,000 US per day for a 50,000 mt vessel. Value shown is for 15 days.

Based on equation 1.5, the value of a GFCS would be $140.34 per railcar using the base case values. In each case, the simulation is made relative to the base case. These are illustrated in Figures 1.1-1.2. Results indicate

- The value of a GFCS increases with the probability of not receiving cars on the want date under alternative allocations. If this probability is zero, GFCS has no value, i.e., if the probability of receiving cars on the want date is 1.0, then the value of a GFCS is nil. As the probability of not receiving cars increases (to 1.0), the value of GFCS increases.

- The value of GFCS decreases with the price spread between the nearby and deferred shipping period. Results illustrate that as the nearby increases relative to the deferred shipping period (i.e., an inversion), the value of GFCS during the first period increases. Literally, as nearby shipping periods command a premium (i.e., an inversion), the value of GFCS during that period increases. The reason for this is that the discount for receiving grain during the deferred period acts as a penalty to the shipper. If the price spread exceeds +8c/b, the value of GFCS diminishes because of forgone earnings from storage.

- The value of GFCS increases with increases in demurrage costs. In this case, if total demurrage costs (per 50,000 mt vessel) are $2,000 per day, the value of GFCS is $35.26 per railcar. For higher demurrage costs, this value increases.

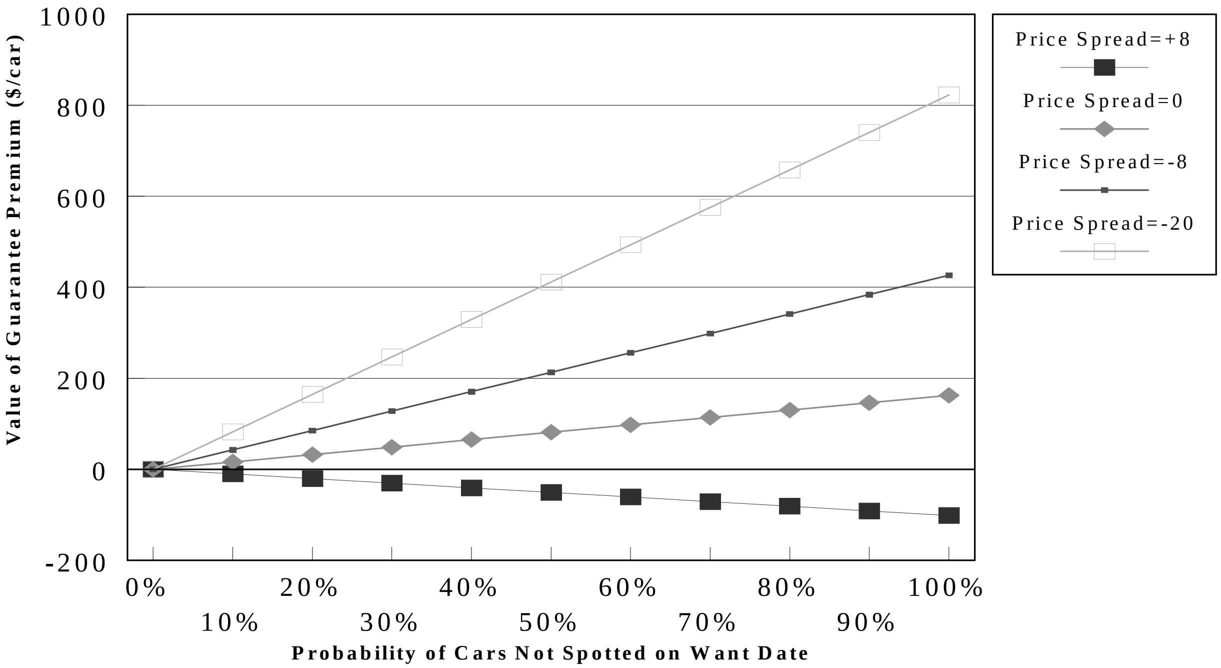

Figure 1.1. Value of Guarantee Premium: by Probability of Receiving Cars for Selected Interperiod Price Spreads (P(t+1)-P(t+2) (c/b)).

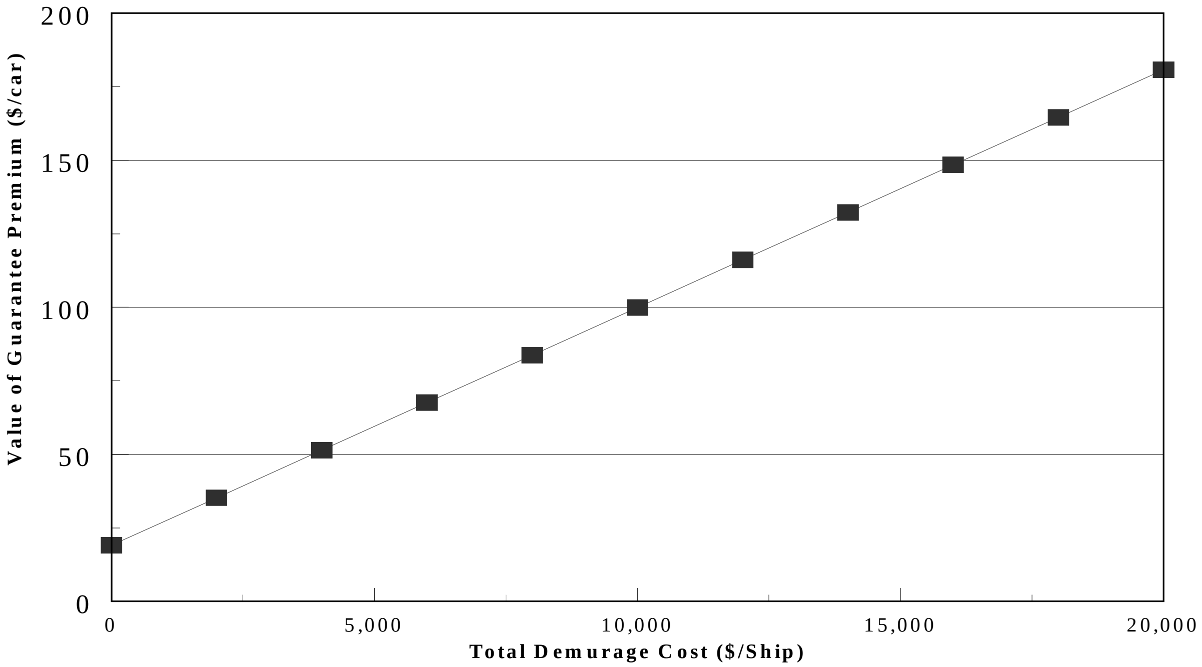

Figure 1.2. Value of Guarantee Premium: Total Demurrage Cost.

Strategic Analysis of Bidding

A crucial aspect of these mechanisms is that allocation and premium are determined using bidding. This is in contrast to using either tariffs or negotiation for pricing or for using historical averages, administrative, or some form of random rationing mechanism for allocation. Bidding, as a mechanism of price determination and allocation among competing shippers, has numerous attractive features and important strategic implications. Game theory models of auctions (e.g., Rasmussen) can be used to analyze strategies of all players simultaneously. The thrust of game theory analyses is on the equilibrium strategies of all bidders and the game outcome and, as such, is useful for analyzing auction rules and revenue equivalency (Vickery).

This section identifies some of the critical aspects of auctions and competitive bidding related to the car allocation problem. A game theoretic model was developed and used to simulate an auction to identify effects of critical parameters. Likely values as they pertain to this problem are used for illustration purposes.

Problem and Auction Types

Since the value of the item, in this case, guaranteed car service for a forward shipping month, is unknown to the railroads, it is unlikely that a posted price would accurately reflect the value. Bidding competition has the effect of forcing shippers to reveal their valuations of forward guaranteed shipping service. Further, the railroad does not know which shipper(s) have the highest value for forward guaranteed car service. An auction has the effect of revealing which shipper(s) have the greatest value. Thus, the crucial effect of auctioning is that shippers are forced to reveal their values and that an optimal allocation and price is nearly automatically achieved.

There are numerous types of auctions, including ascending and descending oral bid auctions and first and second priced sealed bid auctions. In general, these yield similar results from a revenue perspective (Milgrom and Weber, Riley and Samuelson).[14] For practical purposes, the sealed bid auction is used. The important feature of a sealed bid auction is that a shipper bids without knowing the competitors' values, and no opportunity exists for updating the information (as compared to an English ascending bid auction). Thus, shippers are forced to make their own valuations of the GFCS and to formulate expectations about how their competitors bid. It is critical that the competitive environment forces shippers to bid independently. If not, an auctioning process would not be an attractive alternative and/or a reservation price becomes essential (McAfee and McMillan 1987).

As long as their value V_b exceeds that of their competitors, V_c, the optimal bid is just slightly above that of their competitors, $V_c+\epsilon$, where ϵ is an infinitesimally small value. However, not knowing the value of their competitor's bids forces a strategic approach to bidding.

Bidding Models

A first-price, sealed-bid auction among grain traders or shippers was developed. Bidders (players) are grain shippers who compete in their bidding for GFCS, submitting their bids to the auctioneer which is the railroad.

There are two critical functions confronting bidders in bidding competition: first, a profit function, defined as $\pi_i = \hat{V}_i - b_i$ where $\hat{V}_i$ is the expected value of the GFCS for bidder i and b_i is the amount bid. The second is the probability of winning, denoted Prob(b_i), which depends on the amount bid, b_i, and on the intensity of bidding competition. The latter is largely related to the number of bidders bidding in a particular auction. Combining these two functions results in an expected payoff, $E(\pi_i)$. An optimal bid is defined as that bid which yields the maximum expected payoff, considering the tradeoff between higher profits associated with low bids and the lower probability of winning associated with low bids. Technically, the product of these two functions is maximized with respect to b_i to derive the optimal bid. Each bidder maximizes expected profit simultaneously. The solution is solved through an iterative process and the results used to determine the optimal bid for each player.

In sealed bid auctions, each bidder bids simultaneously, without knowledge of competitor bids. They do, however, form expectations about competitors' bids. Competitors' bids depend on two sets of variables. One is the statistical distribution of valuations, V_i. Assuming bidders have different values of GFCS, then the distribution, represented by a standard deviation (i.e.,

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[14] A first-price, sealed-bid auction is an efficient pricing mechanism and is equivalent to a Dutch auction (see Milgrom, 1987, for discussion). In both cases, goods are allocated 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 highest value receives the product, but only at the second lowest price.

derived across values of individual bidders), becomes important. The other set of variables is competitive factors and largely consists of two components. One is the number of bidders (N) in a particular auction; the other is the information possessed by bidders at the time of the auction.

Bidders evaluate their competitive positions and use this information to formulate bids to maximize expected profit. Specifically, distributions reflect players' beliefs about each other's valuations of GFCS which are assumed to have a normal distribution. The expected value and standard deviation of these values are denoted μ_i and σ_i, respectively, for the ith player.

Mean value for player i (μ_i) is determined by a formulation similar to equation 1.5. The standard deviation is a measure of the "quality" of information given that each player has some uncertainty about his/her and his/her competitor's values. 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 value, V_i. Thus, player i's bid is $b_i = s_i * V_i$. By assumption, players commit themselves to a strategy s_i before V_i becomes known to player i, i.e., before nature makes its move. Because bids are a preselected multiple of V (which are unobserved by opponents), they are random.

Player i seeks to maximize the expected payoff:[15]

$$2.1) \qquad E\ (\pi_i) = E\ (V_i - b_i) \cdot \ \text{Prob}(b_i)$$

where (V_i - b_i) represents the payoff from a winning bid and Prob(b_i) denotes the probability of winning. By virtue of our assumptions about V and "preselection" of strategies, opponents' 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 valuations are distributed independently, the probability that player i will win is given by

$$2.2) \qquad \text{Prob}(b_i) = \prod_{-i=1}^{n-1} \left[\int_{-\infty}^{b_i} \frac{1}{\sqrt{2\pi}\ \sigma b_{-i}} e^{-(1/2)[(b_i - \mu b_{-i})/\sigma b_{-i}]^2} db_i \right] \text{ where } -i \neq i.$$

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

$$2.3) \qquad E\ pb(s_i^*, s_{-i}) \geq E\ \pi(s_i, s_{-i}) \quad \forall s_i \neq s_i^*$$

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

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[15] Preszler, Wilson, and Johnson developed a similar model for analyzing price transparency and export wheat tendering.

incentive to deviate from his/her chosen strategy. For the simulations presented in this analysis, Nash solutions were identified through a numerical search procedure.[16]

Simulation Results

Base case assumptions reflect those likely to have existed in the Upper Midwest during the mid 1990s. This is a game with four bidders, each having a mean valuation of $150/car and the standard deviation for each bidder of $50/car. Results for the base model simulations are shown in Table 2.1. Results are symmetric across bidders. The equilibrium bid is $131.66, the probability of winning is .125,[17] and the profit if a bidder wins would be $18.34/mt. The expected profit would be $2.29/mt.[18]

Table 2.1. Equilibrium Bids, Probability of Winning, and Expected

	Player 1	***Player 2***	***Player 3***	***Player 4***
Equilibrium Bid	$131.66	$131.66	$131.66	$131.66
Probability of Winning	.13	.13	.13	.13
Expected Profit for Shippers	$2.29	$2.29	$2.29	$2.29

A graphical depiction of these results is shown in Figure 2.1. Results demonstrate that with higher bids, the probability of winning increases, but the profits associated with winning diminish. In fact, for bids above $150/car, the expected profit would be negative. These latter values are shown in Figure 2.1 and are the maximized function.

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[16] The model was developed and solved using *MathCad*.

[17] The probabilities are each player's assessment of his probability of winning versus not winning and containing his assessment of expected valuations of competitors. Other players, not knowing their rival's valuations, only have a probabilistic assessment of their chance of winning/not winning. As such, these probabilities are conditional probabilities based on the information set available to each competitor and are not additive. Ioannou demonstrates the logic of this conclusion.

[18] Derived as $Prob(b_i)*\pi_i$, or $18.34/mt*.125.

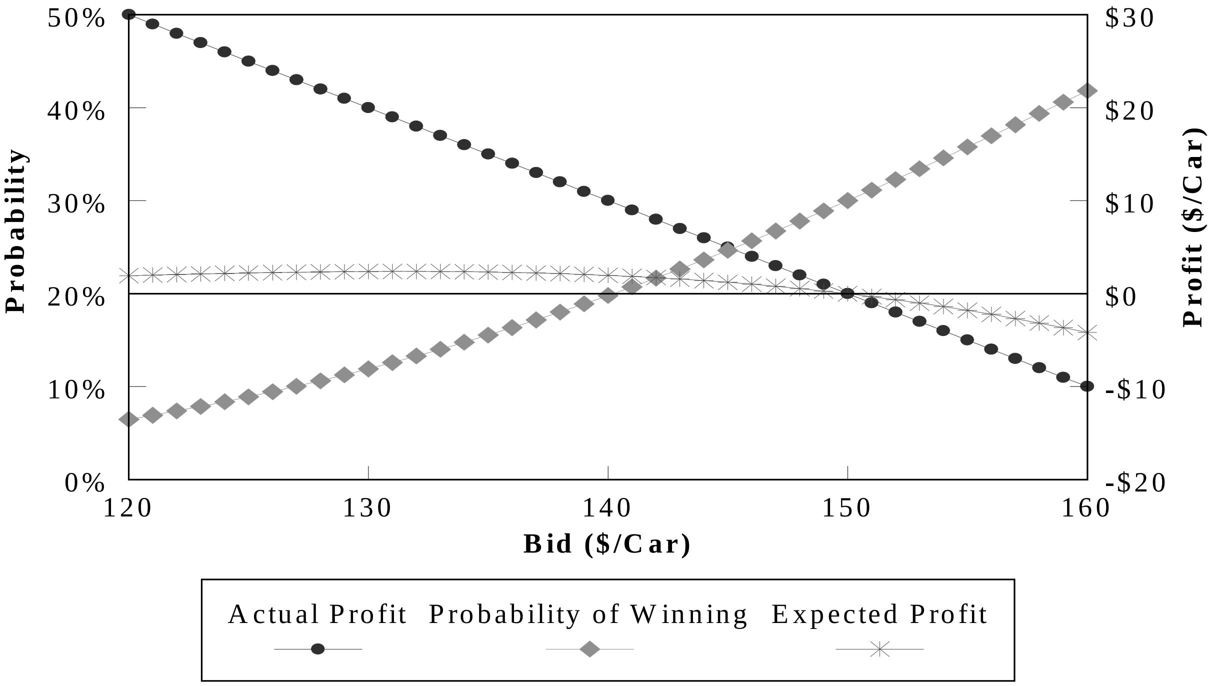

Figure 2.1. Relationship Among Bid Price, Probability of Winning, and Actual and Expected Profit.

Deviations From the Base Case. We used the model to simulate deviations from the base case to illustrate effects of critical variables on the solution. Important elements of contract design can be identified from these results. Results are shown in Figures 2.2-2.4 and Tables 2.2 and 2.3.

- An increase in the number of independent bidders results in more intensive competition among bidders (Figure 2.2). An increase in the number of bidders has the effect of increasing the equilibrium bid (and therefore railroad profit) and decreasing the expected profit for the bidders.

- Bidders with higher values of GFCS will bid higher amounts and have a higher probability of winning than those with lower valuations (Figure 2.3, Table 2.2).

- All bidders have an expected value of the GFCS, about which they have some uncertainty, which is represented by the standard deviation. This could occur due to the variables on the right-hand side of equation 1.5, most notable being the subjective probability of car shortages and demurrage costs. This particular parameter reflects the information relative to competitors. Results indicate that increases in the standard deviation result in lower bids and higher expected profits (Figure 2.4, Table 2.3). Thus, bidders who have greater uncertainty about competitors protect themselves by reducing their bids; and if they win, their profits are greater. For example, in Table 2.3, Player 4 has the highest standard deviation for his expectation of competitors costs. Therefore, players 1-3 take the strategic action of bidding a little more with the effect of winning more often. Player 4 reduces his bid in reference to his costs, such that, for the few times he wins, he obtains a larger profit.

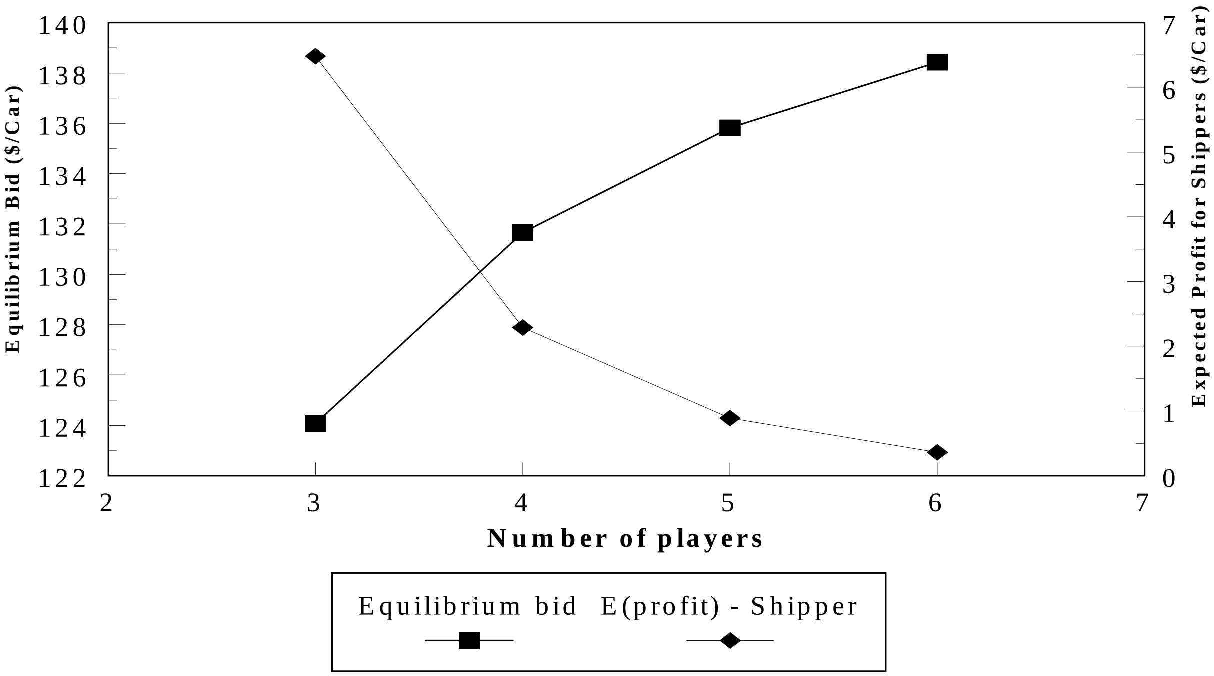

Figure 2.2. Equilibrium Bids and Expected Profit for Shippers with Changes in Number of Players in Bidding Game.

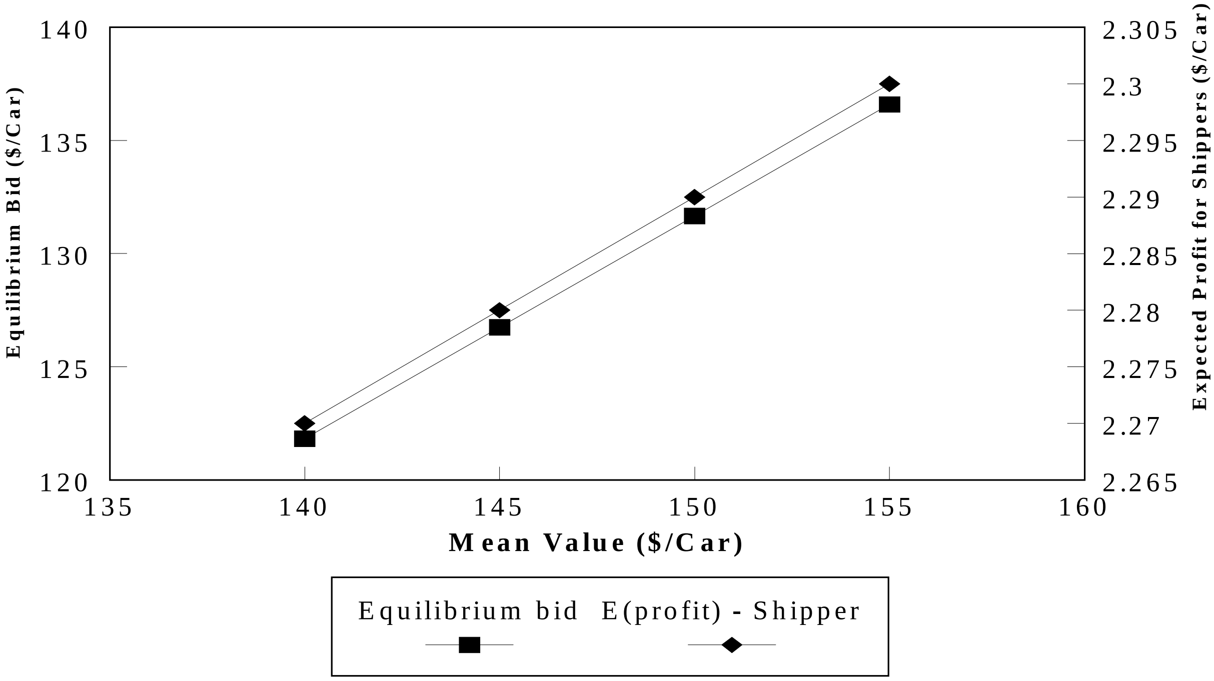

Figure 2.3. Relationship Among Mean Value, Equilibrium Bids, and Expected Profit for 4-player Game.

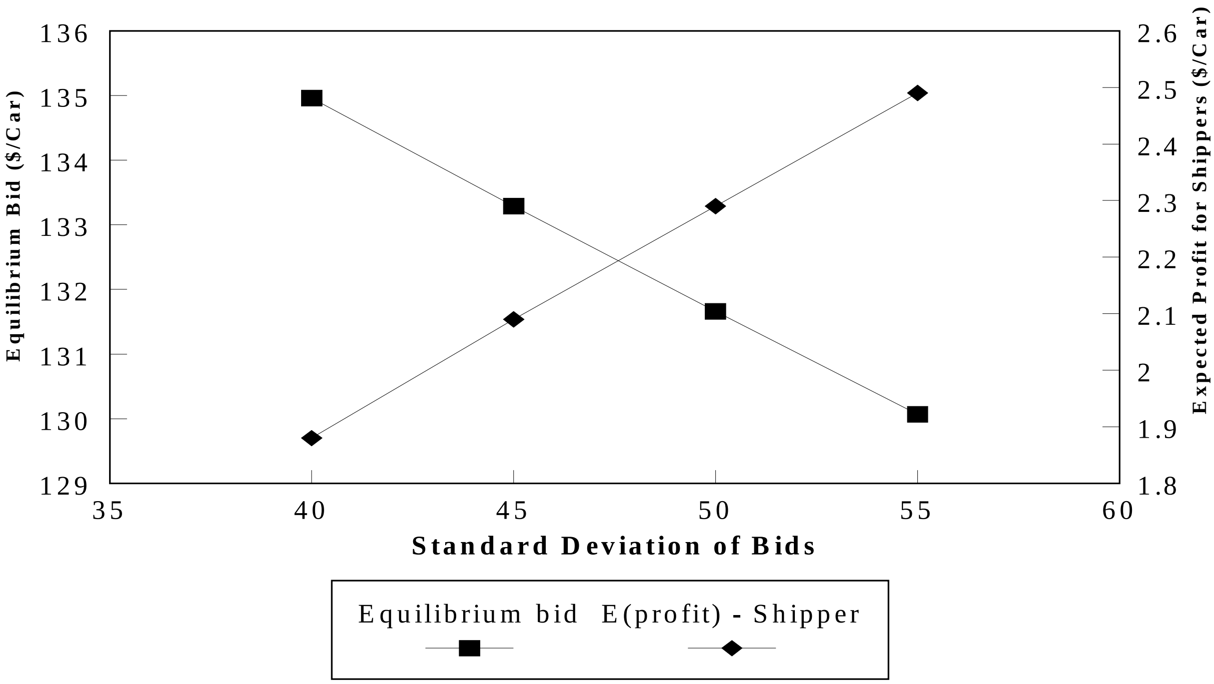

Figure 2.4. Relationship Among Standard Deviation of Bids, Equilibrium Bids, and Expected Profit for Shippers in a 4-player Game.

Table 2.2. Asymmetric Valuations: 4-player Bidding Game

Value of GFCS	**Player 1**	**Player 2**	**Player 3**	**Player 4**
Mean	$140	$145	$150	$155
Std. Deviation	$50	$50	$50	$50
Equilibrium Bid	$121.96	$126.79	$131.61	$136.43
Probability of Winning	.12	.12	.13	.13
Expected Profit for Shippers	$2.15	$2.24	$2.34	$2.44

Table 2.3. Asymmetric Distribution of Valuation: 4-player Bidding Game

Value of GFCS	Player 1	Player 2	Player 3	Player 4
Mean	$150	$150	$150	$150
Std. Deviation	$40	$45	$50	$55
Equilibrium Bid	$134.40	$133.12	$131.80	$130.46
Probability of Winning	.15	.13	.12	.11
Expected Profit for Shippers	$2.32	$2.23	$2.17	$2.14

Summary and Discussion

Some important changes have evolved in the grain shipping industry, escalating the sophistication of the strategic analysis of rail shipping strategies. Most important has been the development of guaranteed forward (GFCS) options. While these are common in other service industries, they are innovative in rail grain shipping which for many decades primarily used first-order first-serve systems to allocate service, resulting in persistent shortages felt similarly across all shippers. An important characteristic of previous schemes was that generally shippers had only one option; and, as a result, all shippers were treated similarly. As a result though, demands for shipping options may have existed, the lack of mechanisms being offered by railroads inhibited the ability of shippers from pursuing strategies.

These forward guaranteed service options were initially integrated into the BN system which had to withstand commercial, political, and legal challenges. Most of the other major rail carriers have since introduced similar mechanisms. Some of the common features of these are they are for forward shipping positions, railroads provide guarantees, most are executed using an auction process and are transferable, and shippers are subject to cancellation penalties. Taken together, these have enabled shippers and carriers to have irrevocable commitments about forward shipments. Transferability has allowed for the inception of a market for forward rail freight which has evolved as an important element of the industry.

This paper explored some of the economic implications of these mechanisms. Pricing and distributional efficiency were described in the context of rail grain shipping. Generally, these mechanisms have a tendency to be more efficient from a pricing perspective by reflecting the value of forward guaranteed shipments to both railroads who can respond in their car supply and shippers in making procurement and shipping decisions. Also, these mechanisms are more allocatively efficient because shippers with the greatest valuation are capable of gaining priority in the allocation process.

A model was developed to identify factors determining the value of the GFCS. The results indicated that the value of GFCS increases with 1) increases in the probability of not receiving cars on the want date under alternatives, 2) increases with the degree of inversion in the commodity market, and 3) increases in time-dependent storage costs and 4) margin differentials between guaranteed and non-guaranteed shipments. The demand for GFCS is comprised of both speculative and hedging components. The former arises if traders expect shipping costs to increase. The latter is attributable to providing security about future shipping requirements. Of particular importance is these components of demand and factors determining the value of GFCS vary both through time, as well as across shippers.

For various reasons, the railroads use auctioning mechanisms to allocate GFCS. The most important is that the value of GFCS is not known by the railroad. As a result of this asymmetric information, auctioning is an efficient mechanism at trying to extract information from bidders, in this case, about the value of GFCS. A game theory model of a sealed bid auction was developed to explore some of the implications of these mechanisms on the formulation of strategies and the effect of critical variables. The results indicate equilibrium bids and strategies for shippers and can be used to evaluate effects of critical variables. There are two effects of particular interest. One is that an increase in the number of bidders results in more intense bidding competition, raising equilibrium bids and reducing shippers' expected payoffs. The second is that an increase in the standard deviation of information about valuations has the effect of reducing equilibrium bids. Shippers subject to greater uncertainty protect themselves by reducing their bids; and if they win, their profits are greater.

Although these are analytical results, they do provide some important conclusions regarding design and operations of a GFCS in the rail shipping industry. These innovations have some important implications for the grain handling industry. First, now shippers have service options which allow them to formulate strategies to manage their risks associated with grain shipping. Since each shipper may adopt different strategies at different costs, it will be less common for shippers to have identical shipping rates (equal to tariffs). Related to this is that since the factors affecting the values of GFCS vary across shippers, there will be important differences in bidding and use of these mechanisms across originators and receivers. Second, use of these mechanisms requires shippers to analyze factors affecting the value of the GFCS, not only for their own operations, but also for that of their competitors, as well as evaluation of competitor bidding and rail shipping strategies. This includes primarily expected values of the variables that determine the value of GFCS. Those shippers with greater informational advantages will have a greater advantage in bidding. The third implication is that increasingly, the importance of being a low cost handler will become apparent. Handlers with lower costs will have greater valuations of forward guaranteed service which would instill advantages to them in terms of bidding.

There are also some important implications for railroads in design of these mechanisms. It is important that one of the primary reasons to use an auction is due to asymmetric information and for the seller to extract information from potential bidders. An important implication for railroads is that the number of bidders is critical in terms of providing competition. These results indicate that the GFCS should be designed to have at least 5-6 independent bidders on a regular basis. If the number of bidders is less, their bids will be less, profits greater, and railroad profits less. Second, information is critical. In fact, the reason for having an auction, in part, is to extract information from shippers regarding their valuations of forward guaranteed shipments. These results suggest that every effort to reduce this uncertainty should be made to provide shippers less risk in their valuation assessments, therefore, increasing their bids and railroad profits.[19]

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[19] An interesting example of this is the BN ACRES program in which shippers have equal access to large amounts of information (e.g., expected fill dates, COTs sold/remaining, etc.) all of which can be used by shippers to assess their future values of guaranteed shipments. The BN and UP have each recently adapted the Internet as the mode of communicating the auction and bidding information.

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