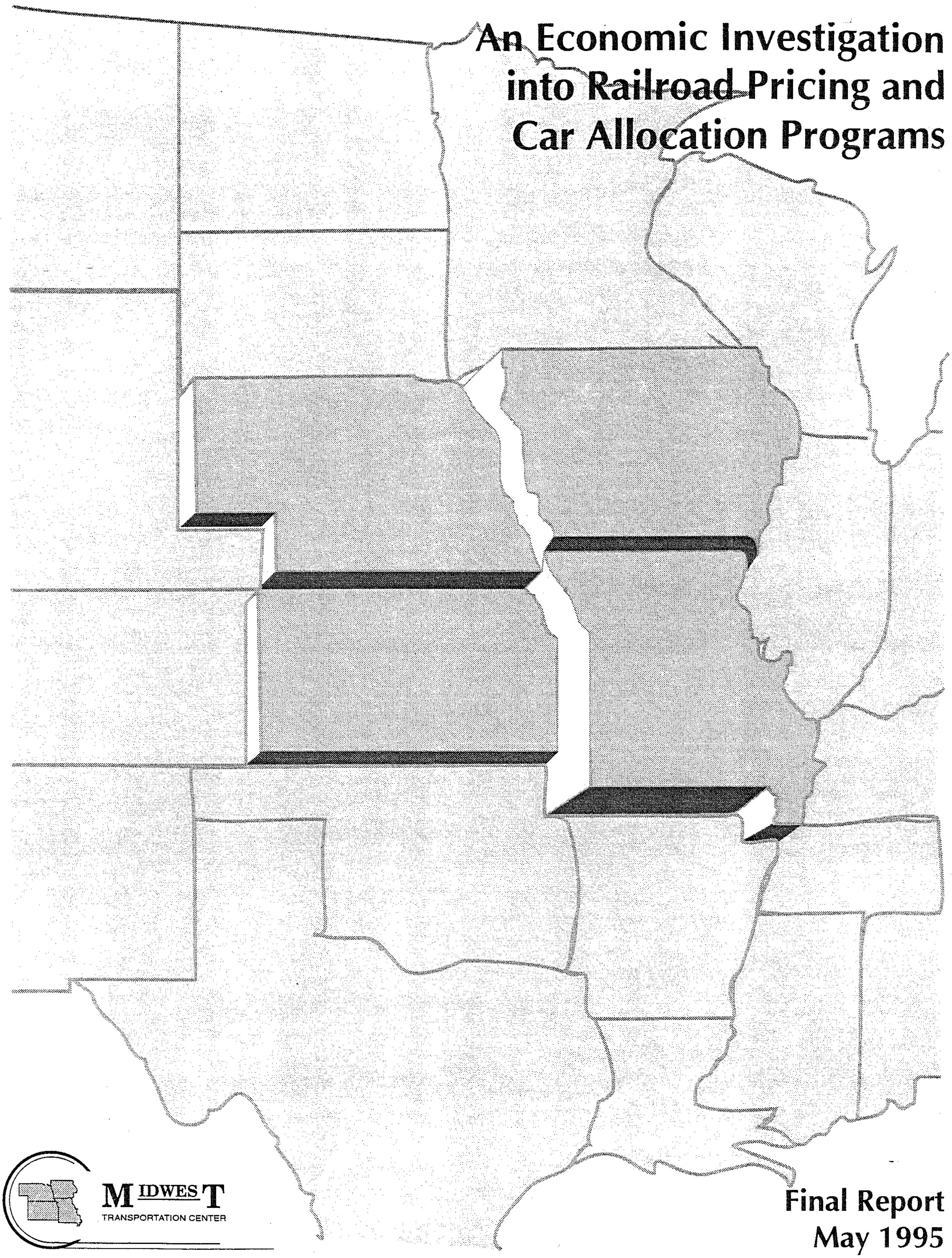
An Economic Investigation into Railroad Pricing and Car Allocation Programs



MIDWEST TRANSPORTATION CENTER

Final Report
May 1995

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INTRODUCTION

Prior to 1980, tariff service was the only type of service offered by railroads. A tariff rate is a posted price which shippers either accept or reject. Shippers order rail cars on a spot basis and railroads allocate cars to shippers on a first-come first-serve basis. Railroads try to meet the shipper requests on a timely basis but service delays may be very lengthy. Currently, railroads must notify shippers 20 days in advance of any rate change. This differs significantly from other modes of grain transportation which possess instant rate flexibility enabling them to quickly respond to changes in demand.

The demand for grain transportation is highly volatile. Grain car loadings to domestic end-users, while trending upward, tend to be relatively stable within each year. Loadings for export markets fluctuate dramatically [Pautsch et al., 1991]. During a surge in the demand for U.S grain exports, the demand increases for all transportation modes. Barge and trucking firms respond by increasing rates thereby making rail transportation with relatively rigid rates more attractive. Hence, shipper demand for rail service at prevailing tariff rates often exceeds railroad capacity. The fluctuating nature of grain exports along with relatively rigid railroad rates cause persistent rail car shortages and surpluses.

The Staggers Rail Act of 1980 substantially deregulated the railroad industry [US Congress, 1980]. The Staggers Act was designed to simultaneously improve the financial condition of the then near bankrupt railroad industry and to enhance service to shippers by improving track conditions and rail car availability. Staggers gave railroads the authority to innovate with new service offerings. The Act encourages railroads to offer premium services which increase the utilization of its assets. This deregulated environment is the foundation for the car-ordering systems presently used in the railroad industry.

Following the passage of the Staggers Act, railroads and shippers began negotiating contracts for guaranteed car supply service. In guaranteed service, the railroad certifies the delivery of rail cars within a specified time window, allowing shippers to avoid lengthy delays in receiving tariff service. Currently, the Burlington Northern Railroad (BN), Union Pacific Railroad (UP), and Canadian Pacific Rail System's "SOO Line Railroad Company" use rail car ordering systems which allow grain shippers to acquire guaranteed service in advance as well as tariff service on a spot basis.

The BN and SOO use auctions to allocate guaranteed service among shippers. Each specifies the amount of guaranteed service to be auctioned for as much as six months in advance. The BN limits the amount of guaranteed service available to less than 40 percent of its projected fleet, while the SOO limit is less than 20 percent. Auction winners are guaranteed delivery of rail cars within a specified two week window. The BN sets minimum acceptable bids for the auction and allows shippers to trade the rights to guaranteed service among themselves in an unstructured secondary market. The SOO does not set minimum acceptable bids and the rights to guaranteed delivery cannot be transferred.

Rather than conducting an auction to allocate guaranteed service, the UP offers guaranteed service at the same rate as tariff service. The UP, however, gives each shipper an upper limit on the amount of guaranteed service it can acquire. The upper limit is based on a four year historical average of railroad provided cars. The UP reasoning for such a system is to increase the equity in the distribution of guaranteed service [Machalaba, 1990].

The new car ordering systems, however, have been met with shipper resistance [ICC, 1991; Goldstein, 1991]. The National Grain and Feed Association (NGFA) had many objections concerning the equitable treatment of shippers in the BN's COT program. First, the NGFA argued the BN receives an unfair informational advantage by disclosing only the winning bids and not all the COT bids [Casavant, 1991]. The BN sets the total number of COTs available and the minimum acceptable bid for each corridor based on the information from all past bids submitted by shippers. Shippers, on the other hand, prepare COT bids and the number of COTs to bid on with the knowledge of only the past winning bids. The NGFA, therefore, contended the BN creates for itself an unfair informational advantage by withholding all the demand information from shippers it receives from the COT auction.

Second, the NGFA contended the BN has the incentive to exploit grain car supply in order to increase revenues [Casavant, 1991]. The NGFA asserted the BN has unfair control over the total number of grain cars on the BN, the allocation of grain cars across BN corridors, and the division of grain cars between COT and tariff service on each corridor. Specifically, the NGFA complained that by setting the minimum acceptable bid and the number of COTs available on a corridor, the BN has the incentive to increase the value of its COT service by decreasing its tariff service reliability. By making tariff service less reliable, shippers needing to move grain over the BN will then submit higher bids in order to ensure the acquisition of grain cars. Furthermore, by controlling the allocation of cars across corridors, the BN is able to manipulate car supply and practice price discrimination in order to maximize profits on individual corridors [Casavant, 1991]. The BN charges a $200 per car fee for changing COT corridors, thus creating a barrier between corridors and segregating them into separate markets.

Third, the NGFA contended the COT program violates the BN's common carrier obligation. A definition of a transporter's common carriage obligation does not appear in case law. However, from historical precedents, it appears to be an obligation to offer transportation service either for the movement of commodities or passengers to all who would demand such service on terms and conditions applicable to all [Pautsch et al., 1991]. Using the common carrier obligation, shippers contend that all shippers in a similar circumstance as a COT recipient should be able to obtain COT service at the same price.

Finally, the NGFA asserted the COT program increases the riskiness of tariff service. The NGFA complains every grain car committed to the COT program reduces the number of cars in tariff service [Casavant, 1991]. During periods of car shortages, as the percentage of grain cars in the COT program increases, the average waiting time for tariff service increases causing greater hardship on shippers using tariff service. Also, the BN established a $50 per car penalty for shippers canceling tariff service increasing the risk associated with ordering tariff service.

The ICC ruled the COT program did not defy any ICC rule or cause the BN to violate its common carrier obligation. An ICC commissioner described the COT program as, "...one of the few truly innovative carrier marketing programs arising out of the Staggers Act" [Cawthorne, 1992]. Another commissioner was encouraged by the steps the BN had taken to address the concerns of small shippers and added the commission would be open to hear future complaints about the COT program [Brown, 1992]. NGFA officials were disappointed in the decision and stated that, "...in major and potentially precedent setting cases such as the this one, the majority of the ICC is issuing decisions that give short shrift to shipper concerns on rail transportation matters" [Cawthorne, 1992].

NGFA officials appealed the ICC decision. The United States Court of Appeals reviewed the ICC decision approving the BN COT program. The Court stated the Commission erred in concluding that the Burlington Northern meets its common carrier obligations because the COT program is available to all shippers and the BN maintains a fleet sufficient to meet average demand.

The Court found that in order to conclude whether the Burlington Northern meets its common carrier obligations to shippers, the Commission must determine if the COT program adversely affects the BN's ability to provide equitable and adequate tariff service on reasonable request [United States Court of Appeals, 1993]

Rather than return to the ICC for settlement, the NGFA and BN chose to negotiate changes in the COT program. Recently, the NGFA dropped its eight-year effort to force significant changes in the BN COT program [Watson, 1995]. Improved market conditions and the questionable future of the ICC were factors in ending their efforts. The BN, however, did provide some revisions in its COT program and the BN supply of cars in tariff service has improved.

Purpose of Research

The purpose of this research is to study the effects of guaranteeing rail service on tariff rates, fleet size, and the welfare of shippers and railroads. The analysis presents simplified models of a pre-Staggers car ordering system offering only tariff service and a post-Staggers car ordering system offering guaranteed service and tariff service. In the models, shippers order tariff service on a spot basis with full information and the railroad fills the car orders on a reactionary basis. The tariff service orders may or not be filled by the railroad. Shippers order guaranteed service in advance without complete knowledge of grain market conditions. But the railroad is assumed to fill all guaranteed car orders.

The pre-Staggers system is characterized by the railroad choosing its tariff rate and capacity before knowing the aggregate demand for tariff service. The post-Staggers system is characterized by the railroad using the advanced guaranteed service orders to make a more informed capacity decision. Furthermore, the advance information concerning demand also allows the railroad to route its assets more efficiently and to reduce operating costs. Tariff service is handled in the same manner as the pre-Staggers system. Finally, guaranteed service is assumed to be offered at the same rate as tariff service. This is similar to the UP car ordering system but contrary to the auctions used by the BN and SOO.

The models presented in this research are restrictive. The models consist of a single period, single market, single mode, and a single carrier. The models also assume homogeneity across shippers with a known grain supply. The restrictions were necessary to simplify the analysis and to obtain initial results. However, the simplified models continue to capture many of the important issues surrounding guaranteed rail service [ICC, 1991].

LITERATURE REVIEW

In the pre-Staggers system, the railroad chooses its tariff rate and fleet size before knowing the aggregate tariff service demand. Once demand is realized, the railroad allocates its existing capacity among the grain shippers. This type of model has been investigated in the peak load pricing literature [Brown and Johnson, 1969 and 1970; Salkever, 1970; Turvey, 1970; Visscher, 1973; Crew and Kleidorfer, 1976; Carlton, 1977; Gellerson and Grosskopf, 1980] and in monopoly models under uncertainty [Mills, 1962; Karlin and Carr, 1962]. The monopolist or utility is assumed to have constant per unit cost of production and capacity. Demand uncertainty was modeled in an additive and multiplicative fashion with various exogenous rationing rules. The effects of incorporating reliability of service constraints were also examined [Meyer, 1975; Crew and Kleindorfer, 1978]. Finally, different rationing mechanisms such as interruptible service [Marchland, 1973; Tschirhart and Jen 1979], ripple control service [Dansby, 1979], self rationing models [Panzar and Sibley, 1978; Schwarz and Taylor, 1987; Oren et al, 1985], and priority service [Chao and Wilson, 1987; Wilson, 1989 and 1991; Viswanathan and Tse, 1989] have been studied.

The post-Staggers system most resembles the literature on priority service. In priority pricing models, the monopolist or utility states a price and reliability of service for a menu of service offerings. Consumers then select the desired quality of service. Available capacity is allocated to the highest reliability class and the remaining capacity is allocated to the next highest priority class. This continues until the entire capacity is used or all customers are served.

In the post-Staggers system, guaranteed service, is never interrupted. Unlike previous priority pricing models, customers are allowed to purchase various quantities of both types of service. Guaranteed service is purchased in advance with customers uncertain as to its value, but not its arrival. Tariff service is acquired later when shippers possess full information, but orders may be rationed.

MODELS

Pre-Staggers System

The pre-Staggers rail car ordering system, as modeled in this analysis, is described in figure 1. The railroad chooses its tariff rate and fleet size without knowing demand. Next, grain shippers with complete grain market information choose the amount of tariff service to order. Shipper tariff service orders are rationed whenever aggregate demand for tariff service exceeds railroad capacity.

Pre-Staggers Shipper Model

Grain shippers are assumed to be identical and possess identical information sets. Each shipper has an initial inventory of grain denoted as y. Grain shippers are assumed to acquire information about their grain salvage value (z) before learning the price of grain (p). After learning its salvage value and price of grain, shippers either order tariff service to sell grain by rail or place the grain in storage. If total demand for tariff service exceeds railroad capacity, car orders are rationed. In this case, grain selected to be sold by rail is stored thereby reducing shipper profit.

Shippers have complete information when ordering tariff service. During car shortages, the rationing rule imposed by the railroad is that railroad capacity is allocated equally among shippers. Therefore, each shipper knows it is unable to influence the amount of tariff service it receives by over-ordering rail cars. Shippers order only the desired amount of tariff service. Each shipper determines the amount of tariff service to order by maximizing profit as shown in equation (1).

$$\max_{q_i^d} \; s\pi_i = (p-t)\,q_i^d + z\,(y-q_i^d) - v\,(y-q_i^d)^2 \qquad (1)$$

where:

$s\pi_i$= profit for the ith shipper.

p= price of grain.

z= grain salvage value.

t= tariff rate.

y= grain inventory.

q^d_i= tariff service demand for the ith shipper.

$y-q^d_i$ = grain the ith shipper desires to salvage.

vm^2= cost of storing m units of grain.

The first order condition, shown in equation (2), implies the shipper equates the marginal revenue from selling grain delivered by rail [p-t] to the marginal revenue from storing and salvaging grain $[z-2v(y-q^d_i)]$.

$$[p-t]-[z-2v(y-q_i{}^d)]=0 \tag{2}$$

For notational convenience, define $\rho=(p-z)/2v$ to be the single random variable dictating shipper demand for tariff service. Similarly, define $\tau=t/2v$ to be a normalized tariff rate. A large (small) ρ represents a high (low) grain price relative to the shipper's net salvage function and shippers desire to move a large (small) quantity of grain by tariff service. Since all shippers are assumed identical, the subscript i is dropped and the shipper tariff service demand function is shown in equation (3).

$$q^{d*}=\min[\max[\rho-\tau+y,0],y]$$

where;

$$\begin{aligned} q^{d*} &= 0 && \text{if } \rho<\tau-y \\ &=\rho-\tau+y && \text{if } \rho\varepsilon[\tau-y,\tau] \\ &= y && \text{if } \rho>\tau \end{aligned} \tag{3}$$

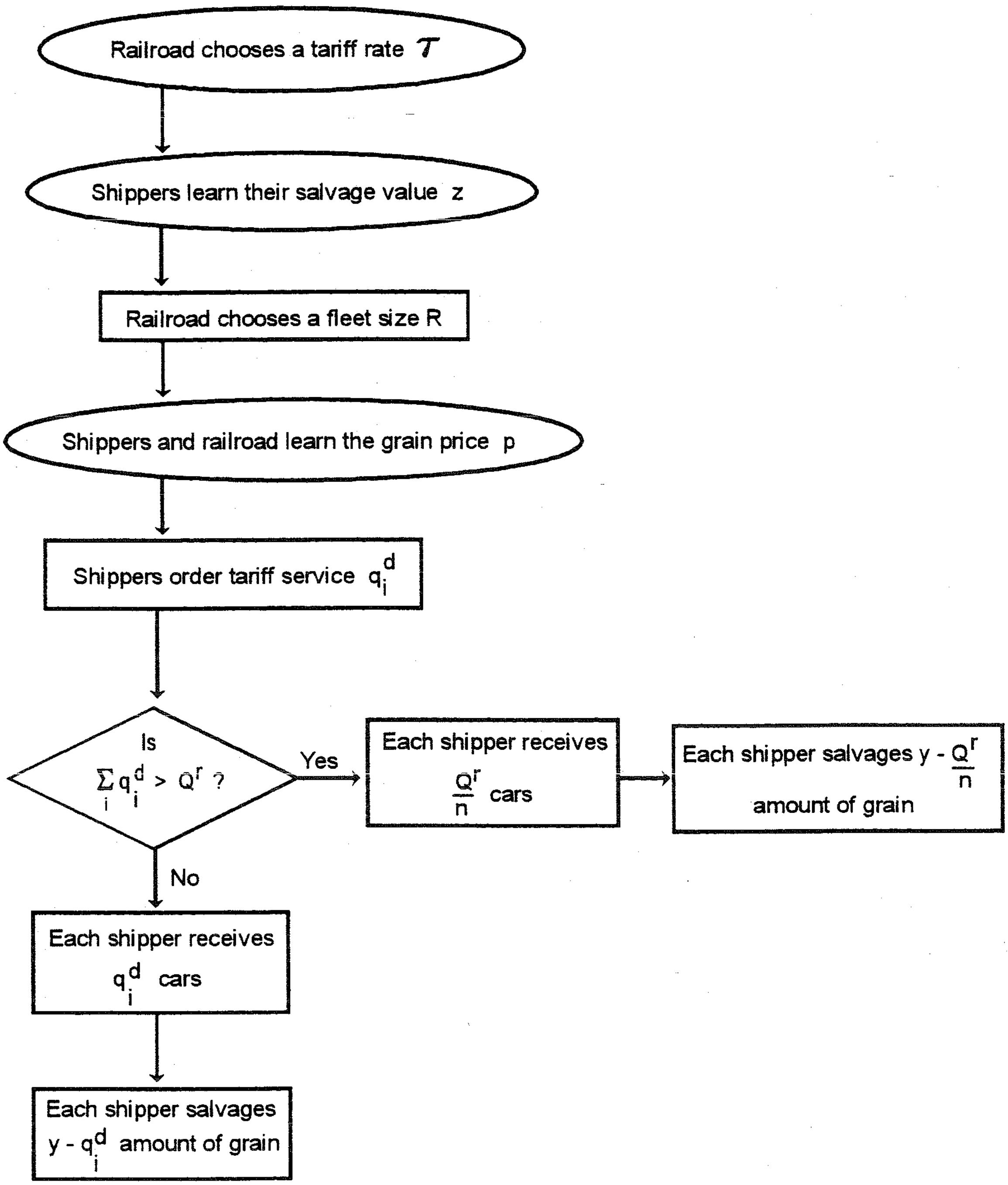

Figure 1. Sequence of decisions for the pre-Staggers car allocation system.

The aggregate demand for tariff service, Q^d, is equal to the number of shippers multiplied by the tariff service demand for a representative shipper.

Pre-Staggers Railroad Model

The production of tariff service depends on the fleet size, tariff rate, and aggregate demand for tariff service. Each rail car is assumed to cost $B and if used in production generates α_n trips. The railroad variable cost is assumed to be linear with a constant marginal operating cost of $b per trip.

The number of rail cars used in the production of tariff service, R_n, is less than or equal to the number of cars in the fleet and less than or equal to the number of cars needed to satisfy shipper demand. The railroad objective of placing the profit maximizing number of cars for the production of tariff service is shown in equation (4).

$$\max_{R_n} \pi = (2v\tau - b)\alpha_n R_n - B\,R \quad \text{subject to } R_n \le R \text{ and } \alpha_n R_n \le Q^d(\rho,\tau) \tag{4}$$

where:

R_n= number of cars placed in tariff service.

α_n= marginal product of a car in tariff service.

R = railroad fleet size.

Q^d= shipper aggregate demand for tariff service.

The first order condition for the unconstrained maximization problem is stated in equation 5.

$$\frac{\partial \pi}{\partial R_n} = \alpha_n[2v\tau - b] \tag{5}$$

Ex ante, the railroad always chooses a tariff rate such that the constant marginal revenue of hauling a grain car is greater than its marginal cost.

Therefore, either the demand constraint or the capacity constraint is binding. The optimal number of cars to put into the production process is denoted as $R_n^*=\min[R, Q^d/\alpha_n]$.

The railroad does not know shipper aggregate demand for tariff service when choosing its tariff rate and fleet size. The railroad knows the probability distributions of p and z and thus knows the probability distribution of $\rho=(p-z)/2v$, which defines aggregate tariff service demand. The railroad uses the probability distribution of ρ, $H(\rho)$, to form its subjective beliefs about shipper aggregate demand for tariff service. The railroad subjective belief that aggregate tariff service demand will be less than or equal to W, $\phi(W)$, is shown in equation (6).

$$\begin{aligned}\phi(W)&=\text{Prob}(Q^d\leq W)=\text{prob}\left(\rho\leq\tau-y+\frac{W}{n}\right)\\&=H\left(\tau-y+\frac{W}{n}\right)\end{aligned}\tag{6}$$

The price at which shipper aggregate tariff service demand equals zero is denoted as $p^o=\tau-y$. Railroad capacity is defined as the fleet size, R, multiplied by the number of trips a car in tariff service completes, α_n. The price at which shipper aggregate demand for tariff service equals railroad capacity is denoted as $p^r=\tau-y+\alpha_n R/n$.

The railroad chooses the fleet size and normalized tariff rate to maximize its expected profit as shown in equation (7).

$$\begin{aligned}&\underset{\tau,R}{\text{Max}}\ E_\rho\left[\pi=(2v\tau-b)\,\alpha_n R_n^*-BR\right]\\&\text{where } R_n^*=\min\left[R,\frac{Q^d(\rho,\tau)}{\alpha_n}\right]\end{aligned}\tag{7}$$

The first order conditions for the railroad optimization problem are stated in equations (8) and (9).

$$\frac{\partial E\pi}{\partial \tau} = E_\rho\left[2v\alpha_n R_n^* + (2v\tau - b)\,\alpha_n \frac{\partial R_n^*}{\partial \tau}\right] = 0$$

$$= \int_{\rho^o}^{\rho^r} [2vn(\rho - \tau + y) - n(2v\tau - b)]h(\rho)\,d\rho$$

$$+ \int_{\rho^r}^{\infty} 2v\alpha_n R h(\rho)\,d\rho = 0 \qquad (8)$$

where;

$$\frac{\partial R_n^*}{\partial \tau} = \quad 0 \qquad \text{if} \quad \rho > \rho^r(\tau, R) \text{ and } \rho < \rho^o(\tau)$$

$$= \frac{\partial Q^d}{\partial \tau}\left(\frac{1}{\alpha_n}\right) \quad \text{if} \quad \rho \in [\rho^o(\tau), \rho^r(\tau, R)]$$

$$\frac{\partial E\pi}{\partial R} = E_\rho\left[(2v\tau - b)\,\alpha_n \frac{\partial R_n^*}{\partial R} - B\right] = 0$$

$$= \int_{\rho^r}^{\infty} [2v\tau - b]\alpha_n \, h(\rho)\,d\rho - B = 0 \qquad (9)$$

where:

$$\frac{\partial R_n^*}{\partial R} = 0 \quad \text{if} \quad \rho < \rho^r(\tau, R)$$

$$= 1 \quad \text{if} \quad \rho \geq \rho^r(\tau, R)$$

The railroad chooses the optimal tariff rate such that the expected marginal profit with respect to the tariff rate during car shortages plus the expected marginal profit with respect to the tariff rate during car surpluses is equal to zero. The expected marginal railroad profit during car shortages is always non-negative. During car shortages, railroad output remains at capacity with tariff rate changes. However, the expected marginal railroad profit during car surpluses declines as the tariff rate rises and eventually becomes negative. The decrease in expected profits during car surpluses is due to the reduction in tariff service demand as a result of a higher tariff.

During rail car shortages, the railroad acquires a fleet size such that the marginal cost of an additional car is equal to the expected marginal revenue of a car. The marginal revenue of an additional car during car surpluses is zero, since the additional car will not be used.

The pre-Staggers equilibrium is characterized in (z,p) space as shown in figure 2. The ray AD represents the combination of salvage values z and grain prices p such that shippers receive all the cars they desire and railroad assets are fully utilized. The combinations below the line result in railroad assets being fully utilized but shippers are rationed. The combinations above the line result in shippers receiving all the cars they desire but a portion of the railroad fleet is idle. The persistent car shortages and surpluses prevalent in the railroad industry occur because the railroad chooses its tariff rate and capacity before knowing demand.

Post-Staggers System

The sequence of decisions of the post-Staggers car ordering system, as modeled in the analysis, is shown in figure 3. Shippers have incomplete information when ordering guaranteed rail service [Dallegge, 1991; Velder, 1991]. Shippers know their salvage value but do not know the future grain price. Shippers order guaranteed service to insure against the possibility of having their tariff car service orders rationed [Reagan, 1991; Guthrie, 1991; Zimmer, 1991]. In the analysis, a low salvage value implies shippers place a high value on rail transportation, indicating the possibility of a large demand for tariff service when the price of grain is revealed. In this case, shippers believe

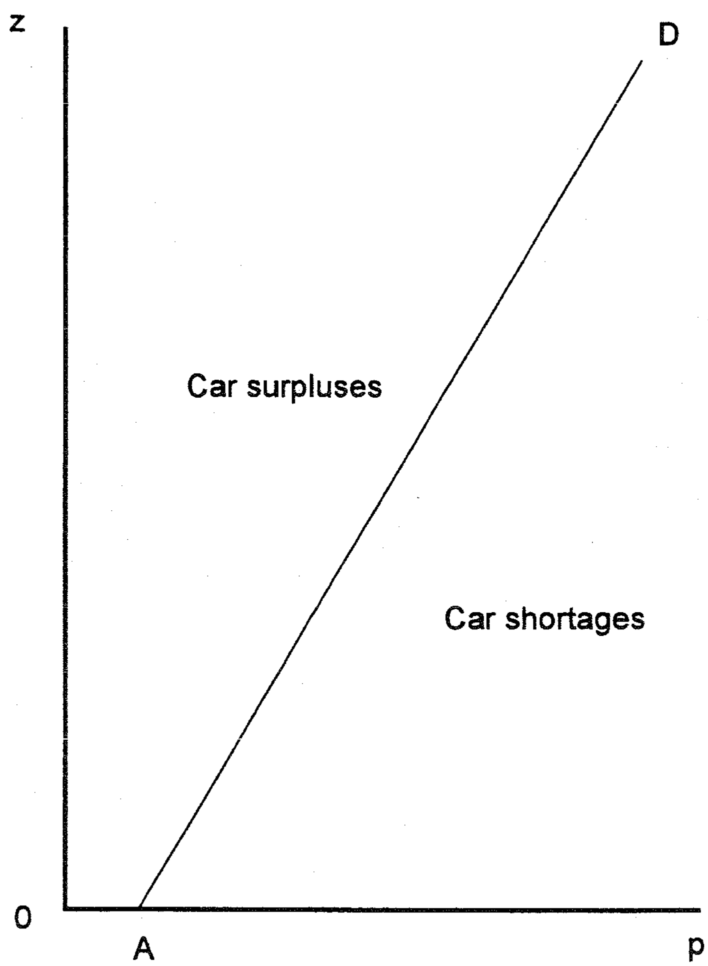

Figure 2. Tariff service equilibrium.

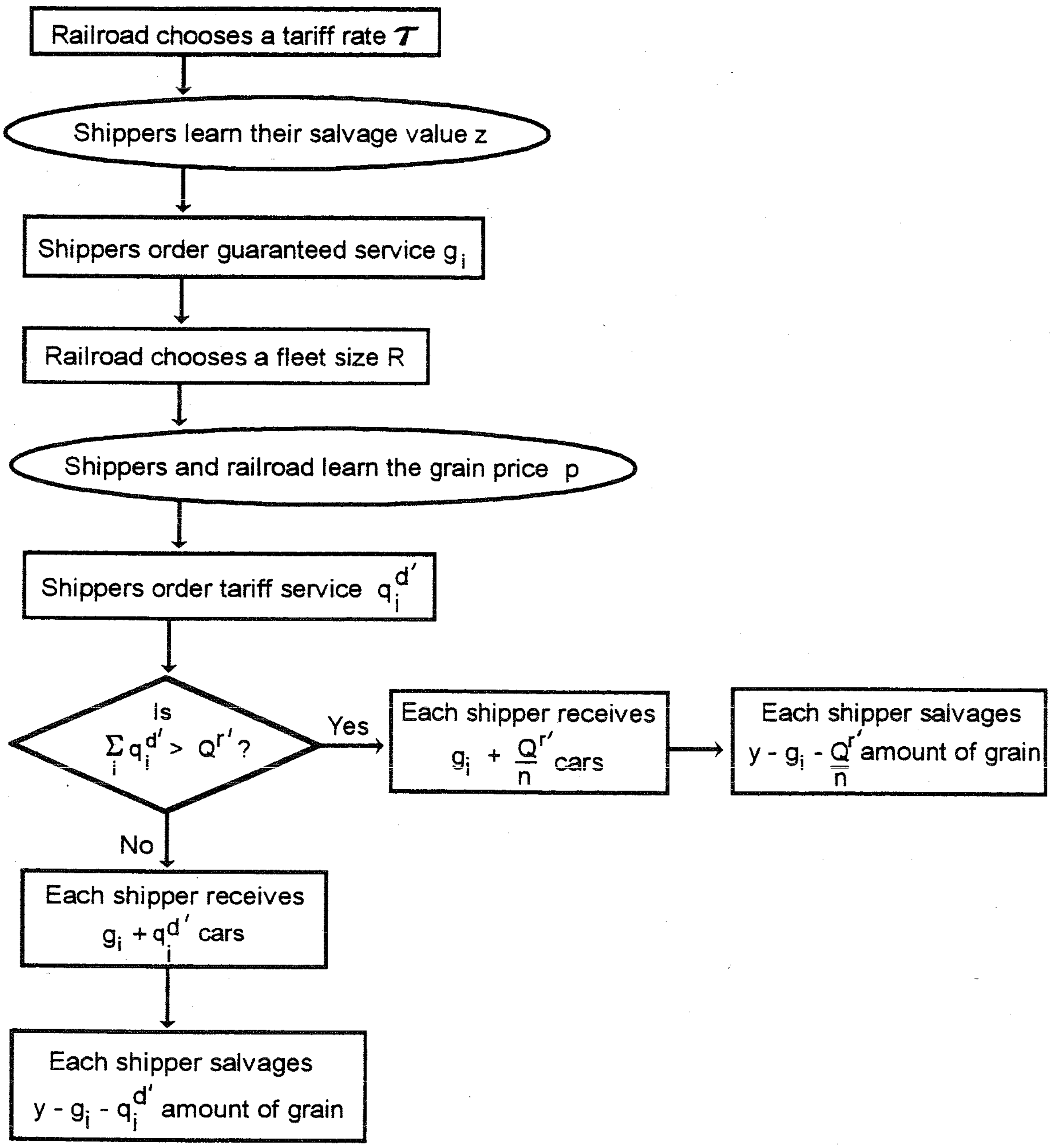

Figure 3. Sequence of decisions with guaranteed service.

that there is a large probability that tariff service will be rationed. Consequently, the aggregate demand for guaranteed service increases. Hence, the aggregate amount of guaranteed service ordered by shippers is assumed to be a monotonically decreasing function of z.

The railroad determines fleet size based on the aggregate amount of guaranteed service ordered. The BN uses the COT market values and bidding activity for COTs to reflect future transport demand conditions and uses the information in capacity decisions [Wilson, 1991]. This is called the informational effect from guaranteeing rail service. If the railroad receives a large number of guaranteed service orders, the railroad knows shippers do not have an attractive alternative to rail service and expect a larger than average demand for tariff service. The railroad accumulates a larger fleet of rail cars to serve the larger than average expected tariff service demand. Hence, railroad fleet size is expected to be a monotonically increasing function of the aggregate amount of guaranteed service ordered.

Guaranteed service also provides the railroad with certain information as to the commodity volume to be shipped, the corridor on which it moves, and the future point in time of the movement. Tariff service orders do not provide the railroad with such reliable and precise information, since orders could be canceled up to 15 days prior to the movement. The information provided to the BN from its tariff service orders is of lesser operational and marketing value than guaranteed service orders [Sperry, 1991]. The railroad uses the information from guaranteed service to increase the efficiency of its cars by reducing car cycle times [Sperry, 1991]. This is called the rail car productivity effect from guaranteeing service.

For the analysis to be time consistent, shippers simultaneously learn their salvage value, the aggregate demand for guaranteed service, and fleet size response of the railroad. The railroad then extracts the shipper salvage value z from the aggregate guaranteed service orders before choosing its fleet size. The post-Staggers sequence of decisions is altered for time consistency in the following fashion. First, the railroad determines the rail rate τ. Next, shippers learn their salvage value. The railroad simultaneously chooses its fleet size with the n shippers choosing their optimal guaranteed service order. The railroad chooses a fleet given its expected aggregate amount of guaranteed service ordered, while shippers order guaranteed service given its expected railroad fleet. The railroad and shippers expectations are assumed to be accurate. Tariff service is handled in the same manner as in the pre-Staggers system. The new decision sequence simplifies the analysis and maintains the mathematical and informational structure of the problem.

Post-Staggers Shipper Model

The optimal amount of tariff service to order under the post-Staggers system, $q_i^{d'}$, is the same as under the pre-Staggers car allocation system, q_i^d, except the shipper must load all the guaranteed cars previously acquired, g_i. The ith shipper demand for tariff rail service is reduced by the guaranteed service previously purchased. Hence, the ith shipper demand for tariff service under the post-Staggers system is written as $q_i^{d'}=\max[0,q^d-g_i]$. The aggregate demand for tariff service under the post-Staggers system is sum of the n shippers demands and is denoted as $Q^{d'}$.

Shippers, however, may not receive their entire tariff service order. If the aggregate demand for tariff service is greater than tariff service capacity of the railroad, $Q^{r'}$, each shipper receives an equal portion of the tariff service capacity. During a car surplus, each shipper receives all of the tariff service it orders. The amount of tariff service a shipper receives under the post-Staggers system is denoted as $k_i'=\min[q_i^{d'}, Q^{r'}/n]$.

Shippers are able to determine the probability of being rationed. Upon learning its salvage value z, shippers infer both the aggregate demand for guaranteed service and the railroad fleet size. Furthermore, shippers are assumed to believe they are small enough that they do not have a significant affect on the aggregate demand for guaranteed service.

The probability of tariff service being rationed is equal to the probability of the grain price being above some critical level. Let the price, p_i^r, denote the critical grain price given τ and z at which the ith shipper tariff service demand is equal to the ration quantity of tariff service. Grain prices below (above) the critical price, p_i^r, indicate shippers (do not) receive their entire tariff service car order. Let $\phi(Q^{r\prime}/n)$ denote the shipper's subjective belief that its demand for tariff service is less than or equal to its rationed share of the tariff service capacity. Hence, $1-\phi(Q^{r\prime}/n)$ denotes the shipper's subjective belief its tariff service car order will be rationed as shown in equation (10).

$$\begin{aligned} 1-\phi\left(\frac{Q^{r\prime}}{n}\right) &= \text{prob}\left(q_i^{d\prime} \geq \frac{Q^{r\prime}}{n}\right) \\ &= \text{prob}\left(\frac{p-t-z+2v(y-g_i)}{2v} \geq \frac{Q^{r\prime}}{n}\right) \\ &= \int_{p_i^r}^{\infty} m(p)\,dp \end{aligned} \quad (10)$$

where:
$p_i^r = z + 2v\rho - 2vy + 2vg_i + (2vQ^{r\prime})/n$.
$m(p)$=grain price density function.

Shipper profit depends on the total amount of guaranteed and tariff rail service received from the railroad. The amount of tariff service the ith shipper receives, k_i', depends on the amount of guaranteed service ordered and the realized grain price. The railroad is assumed to fill all guaranteed car orders but tariff service orders may be rationed. Shippers choose guaranteed service before knowing the grain price p. Hence, shippers choose the amount of guaranteed service which maximizes their expected profits as shown in equation (11).

$$\mathrm{Max}_{g_i}\; E_p\left[(p-2v\tau)(g_i+k'_i)+z(y-g_i-k'_i)-v(y-g_i-k'_i)^2\right] \quad (11)$$

The first order condition, equation (12), states that shippers equate the marginal expected benefits from guaranteed service during car shortages to the marginal expected loss from using guaranteed service when salvaging grain.

$$\int_0^{p_i^o}[p-p_i^o]\,m(p)\,dp+\int_{p_i^r}^{\infty}[p-p_i^r]\,m(p)\,dp=0 \quad (12)$$

where:

$$p_i^o=z+2v\tau-2vy+2vg_i$$

$$p_i^r=z+2v\tau-2vy+2vg_i+2v\left[\frac{Q^{r\prime}}{n}\right]$$

Shippers purchase guaranteed service in advance without exact knowledge of their transport needs. Shippers must use all the guaranteed service ordered. The cost of guaranteed service to a shipper is the reduced flexibility to market its grain once the price of grain is revealed. The shipper prefers to salvage grain when the grain price falls below p_i^o. The shipper, however, must use the guaranteed rail service which reduces its expected profits. The guaranteed service cancellation fee used in current car ordering systems has comparable private effects to shippers.

During car shortages, shippers receive their ration quantity of tariff service plus the amount of guaranteed service ordered. Shippers believe the size of their guaranteed car order has no affect on their ration quantity of tariff service.

Hence, shippers believe guaranteed service increases the amount of grain it moves by rail during extremely profitable conditions, thereby increasing its expected profits.

Post-Staggers Railroad Model

The railroad fleet, R, is divided into the production of guaranteed and tariff service. The number of cars used to produce guaranteed service is equal to the amount of guaranteed service shippers previously ordered, G, divided by the number of trips a rail car in guaranteed service completes, α_g. The remaining cars, $R-G/\alpha_g$, comprise the tariff service fleet. The tariff service capacity of the railroad is defined as the tariff service fleet multiplied by the number of trips a car in tariff service completes, α_n. Therefore, tariff service capacity under the post-Staggers system is denoted as $Q^{r'}=\alpha_n[R-G/\alpha_g]$.

The production of tariff service by a railroad under the post-Staggers system is similar to the pre-Staggers car system. Again, the tariff decision ensures the marginal revenue of a car in tariff service exceeds its marginal cost. Hence, the cars used in tariff service is constrained either by the railroad tariff service fleet, $R-G/\alpha_g$, or shipper demand, $Q^{d'}/\alpha_n$. The optimal number of rail cars used in tariff service is denoted as $R_n^{*'}=\min[R-G/\alpha_g, Q^{d'}/\alpha_n]$.

By offering guaranteed service, the railroad is assumed to make a more informed fleet size decision. The railroad's expected amount of aggregate service ordered implies an expected salvage value. The grain price, however, continues to be unknown to the railroad when deciding its fleet. The railroad uses the grain price density function, m(p), rather than the joint distribution of p and z, to form its subjective beliefs about aggregate tariff service demand. The railroad's subjective belief that aggregate demand for tariff service is zero is equal to the probability the grain price is less than or equal to $p^{\circ}(\tau,z)=z+2v\tau-2vy+2vG$. Similarly, the railroad's subjective belief its entire fleet will be active is equal to the probability the grain price is greater than or equal to $p^r(\tau,z,R)=z+2v\tau-2vy+2vG+[2vQ^{r'}]/n$.

When choosing its tariff rate, the railroad does not know either the shipper salvage value z nor grain price p. The railroad knows their probability distributions and uses the joint probability distribution to form its subjective beliefs regarding aggregate guaranteed service and aggregate tariff service demand.

The railroad first chooses the rail rate τ, then the railroad and shippers learn the salvage parameter z. The n shippers choose the amount of guaranteed service to order simultaneously with the railroad choosing its fleet size. The shipper's choice of guaranteed service given a fleet size is characterized by equation (12). The railroad choice of a fleet which maximizes its expected profits given the aggregate guaranteed car orders is shown in equation (13).

$$\begin{aligned} &Max_R\ Err\pi=E_p\Big[(2v\tau-b)\ (\alpha_n R_n^*+G)\ -BR\Big] \\ &where\ \ R_n^*=\min\left[R-\frac{G}{\alpha_g},\ \frac{Q^{d'}(p,z,\tau)}{\alpha_n}\right] \end{aligned} \tag{13}$$

The first order condition is shown in equation (14).

$$\begin{aligned} \frac{\partial Err\pi}{\partial R}&=E_p\left[(2v\tau-b)\,\alpha_n\frac{\partial R_n^*}{\partial R}-B\right]=0 \\ &=\int_{p^r(\tau,R,G)}^{\infty}(2v\tau-b)\,\alpha_n m(p)\,dp\ -B=0 \\ \text{where}& \\ p^r&=2v\tau+z-2vy+\frac{2v\alpha_n R+2v(1-\theta)G}{n} \\ \theta&=\frac{\alpha_n}{\alpha_g} \end{aligned} \tag{14}$$

If the fleet is fully utilized ($p \geq p^r$), adding an extra car increases the number of cars producing tariff service, R_n^*. The marginal revenue of the car is equal to the marginal revenue per trip ($2v\tau - b$) multiplied by the number of trips the car completes (α_n). If a portion of the fleet is idle ($p \leq p^r$), the additional car is not used and fails to generate revenue. The railroad equates the expected marginal revenue of a car to the marginal cost of acquiring a car.

Once the grain salvage value z is known, the railroad optimal fleet condition, $R^*(\tau, z)$, and the n shipper guaranteed car order conditions are solved simultaneously. The railroad, however, chooses its tariff rate to maximize its expected profits without knowing z as shown in equation (15).

$$\begin{aligned}&\text{Max}_\tau\ Err\pi = E_{p,z}\Big[(2v\tau - b)\big(\alpha_n R_n^* + G(\tau, z)\big) - BR^*(\tau, z)\Big]\\&\text{where}\quad R_n^* = \min\left[R - \frac{G(\tau, z)}{\alpha_g},\ \frac{Q^{d\prime}(p, z, \tau)}{\alpha_n}\right]\end{aligned} \qquad (15)$$

The first order condition is stated in equation (16).

$$\begin{aligned}&\frac{\partial Err\pi}{\partial \tau} = E_{p,z}\left[2v(\alpha_n R_n^* + G) + \left(\alpha_n \frac{\partial R_n^*}{\partial \tau} + \frac{\partial G}{\partial \tau}\right)(2v\tau - b)\right] = 0\\&\text{where}\\&\frac{\partial R_n^*}{\partial \tau} = 0 \qquad \text{if } R_n^* = 0\\&\qquad = \frac{1}{\alpha_n}\left(\frac{\partial Q^d}{\partial \tau} - \frac{\partial G}{\partial \tau}\right) \quad \text{if } R_n^* = \frac{Q^{d\prime}}{\alpha_n}\\&\qquad = -\frac{1}{\alpha_g}\left(\frac{\partial G}{\partial \tau}\right) \quad \text{if } R_n^* = R - \frac{G}{\alpha_g}\end{aligned} \qquad (16)$$

The railroad chooses the tariff rate such that the expected marginal profit with respect to the tariff rate during car shortages plus the expected marginal profit with respect to the tariff rate during car surpluses is equal to zero. If the grain price is below p^o, the demand for tariff service is zero. Hence, no cars will be used in tariff service. Any infinitesimal change in the tariff will not change these results. If the grain is above p^r, the demand for tariff service exceeds the tariff service fleet. In this case, the entire tariff service fleet is in the production process. An infintesimial change in the tariff rate affects the tariff service fleet only through the amount of guaranteed service. The railroad fleet size decision is optimized after the tariff decision. Hence, the effect of a change in the fleet size (R^*) due to a change in the tariff rate is eliminated by the envelope theorem.

If the grain price is in the interval $[p^o, p^r]$, only a portion of the tariff service fleet is used to satisfy tariff service demand. In this interval, guaranteed service demand replaces tariff service demand. The shipper demand for tariff ser-vice under the post-Staggers system ($Q^{d'}$) is equal to the shipper demand under the pre-Staggers system (Q^d) minus the demand for guaranteed service (G).

The first order condition is rewritten in terms of the individual random variables p and z as shown in equation (17).

Numerical Example

Analytical solutions could not be obtained for the equations describing the post-Staggers car ordering system. A numerical example is presented to shed light on the effects from guaranteeing rail service.

The grain price p is assumed to follow a truncated normal distribution in the interval [$7,700, $11,200] with an expected value of $9,450. These numbers are based on 3,500 bushels of grain in a rail car and the per bushel grain price being in the interval [$2.20, $3.20] with an expected value of $2.70. The salvage value z is assumed to be trinomially distributed with 1/3 probability assigned to

$$\frac{\partial Er\pi}{\partial\tau}=\int_0^{p^o}\int_{-\infty}^{\infty}\left[2vG(z)+\frac{\partial G}{\partial\tau}(2v\tau-b)\right]\gamma(z)m(p)\,dz\,dp$$

$$+\int_{p^o}^{p^r}\int_{-\infty}^{\infty}\left[2vQ^d(p,z)+(2v\tau-b)\frac{\partial Q^d}{\partial\tau}\right]\gamma(z)m(p)\,dz\,dp$$

$$+\int_{p^r}^{\infty}\int_{-\infty}^{\infty}2v[\alpha_n R+(1-\theta)G(z)]\gamma(z)m(p)\,dz\,dp$$

$$+\int_{p^r}^{\infty}\int_{-\infty}^{\infty}\left[(2v\tau-b)(1-\theta)\frac{\partial G}{\partial\tau}\right]\gamma(z)m(p)\,dz\,dp=0 \qquad (17)$$

where:

$$p^o=z+2v\tau-2vy+\frac{2vG}{n}$$

$$p^r=z+2v\tau-2vy+\frac{2v\alpha_n R+(1-\theta)G}{n}$$

$$\theta=\frac{\alpha_n}{\alpha_g}$$

$\gamma(z)$=density function of z

each of the following values $Ez-\epsilon$, Ez, and $Ez+\epsilon$, where Ez=\$5,950 (or \$1.70 per bushel) and ϵ=100, 200, or 300 represents the spread of the distribution. With these assumptions, the expected value of ρ $(p-z/2v)$ is equal to 25. Table 1 presents the remaining data used in the numerical example.

Table 1. Data for the numerical example.

Shipper car loads of grain in inventory (y)	= 25
Shipper storage parameter (v)	= \$70
Expected value of ρ $[E\rho=(Ep-Ez)/2v]$	= 25
Total railroad cost of producing a trip (C)	= \$3,000
Monthly trips by a car in tariff service (α_n)	= 1.5
Monthly trips by a car in guaranteed service (α_g)	= 1.5 or 1.65
Number of shippers (n)	= 100

The grain shipper monthly inventory is assumed to be 25 cars or 87,500 bushels of grain. The number of trips a car in tariff service completes is assumed to be 1.5 trips per month. This estimate is average number of trips a rail car in tariff service completed during 1981 through 1987 for the BN [Sperry, 1991]. The total railroad cost of producing a trip, $3000, is based on the railroad variable cost of moving grain from Sioux City, IA to Portland, OR [Tolliver....] and the monthly rail car cost [Baumel, 1990].

The value of λ allows per unit operating costs and per unit capacity costs to change leaving the total per unit production cost unchanged. The total constant per unit cost of producing output is denoted as C. Per unit operating costs, b, are represented by λC and per unit capacity costs, $B'=(B/\alpha_n)$, are represented by $(1-\lambda)C$. Increasing (decreasing) λ increases (decreases) unit operating costs and decreases (increases) unit capacity costs. Altering the value of $\lambda \epsilon [0,1]$ allows the examination of various railroad cost situations. In the extreme, $\lambda=0$ implies all of the railroad costs are capacity costs and $\lambda=1$ implies all of the railroad costs are operating costs.

RESULTS

The following four sections isolate the impacts of guaranteed service on the railroad and shipper decisions and welfare. First, the following effects of guaranteed service are discussed: the shipper externality, informational gains, and rail car productivity gains. Second, the effects of limiting the amount of guaranteed service ordered by shippers is discussed.

Shipper Externality

Each shipper believes it is small enough that its order of guaranteed service will not significantly affect the aggregate amount of guaranteed service ordered. As a result, shippers believe their ration quantity of tariff service is not affected by their individual guaranteed car orders. In reality, however, a one unit increase in a guaranteed service order does not imply one more unit will be shipped. For example, assume away rail car productivity gains and informational effects from guaranteeing service. Hence, $\theta=1$ and the fleet size remains constant regardless of the amount of guaranteed service ordered. In this case, individual shippers ordering guaranteed service are worse off than under the pre-Staggers program. The shipper believes the expected benefits from ordering guaranteed service is the increased profits during tariff service car shortages. However, in a symmetric equilibrium, each shipper increasing g_i does nothing to decrease the aggregate probability of being rationed. In fact, guaranteed service is produced at the expense of tariff service. The expected benefits from ordering guaranteed service is actually zero. The costs of guaranteed service continue to be the flexibility loss in marketing grain once the grain price is revealed. Hence, shipper expected profit actually falls with guaranteed service.

Informational Gains

By guaranteeing service, railroads are able to extract the additional market information held by shippers regarding their grain salvage value z. Consequently, the railroad becomes better informed about future shipper demand for tariff service and acquires a more suitable fleet. To examine the informational impact of guaranteeing service, rail car productivity effects are eliminated by assuming $\theta=1$.

Figure 4 shows the expected railroad profit for a car allocation system with guaranteed service and the pre-Staggers system. The informational effect of guaranteed service is to increase expected railroad profit. The increase in expected railroad profits is due to tariff rate changes, the ability to lock in business, and the ability to acquire a more appropriate tariff service fleet.

Figure 5 shows that when capacity costs are relatively high ($\lambda \leq 0.3$) the tariff rate is greater with guaranteed service than in the pre-Staggers system. In these instances, tariff service demand at the pre-Staggers tariff rate is insufficient for the railroad to acquire a tariff service fleet. Also, the guaranteed service demand at the pre-Staggers rate is too high for the railroad to maximize profits. To increase its profits beyond the pre-Staggers level, the railroad increases the tariff rate to choke off demand for guaranteed service.

When capacity costs are lower and the fear of rationing is decreased, the railroad produces guaranteed and tariff service. In order to lock in business and encourage shippers to purchase guaranteed service without full knowledge of grain market conditions, the railroad decreases its tariff rate. In these cases, the tariff rate with guaranteed service is lower than in the pre-Staggers system.

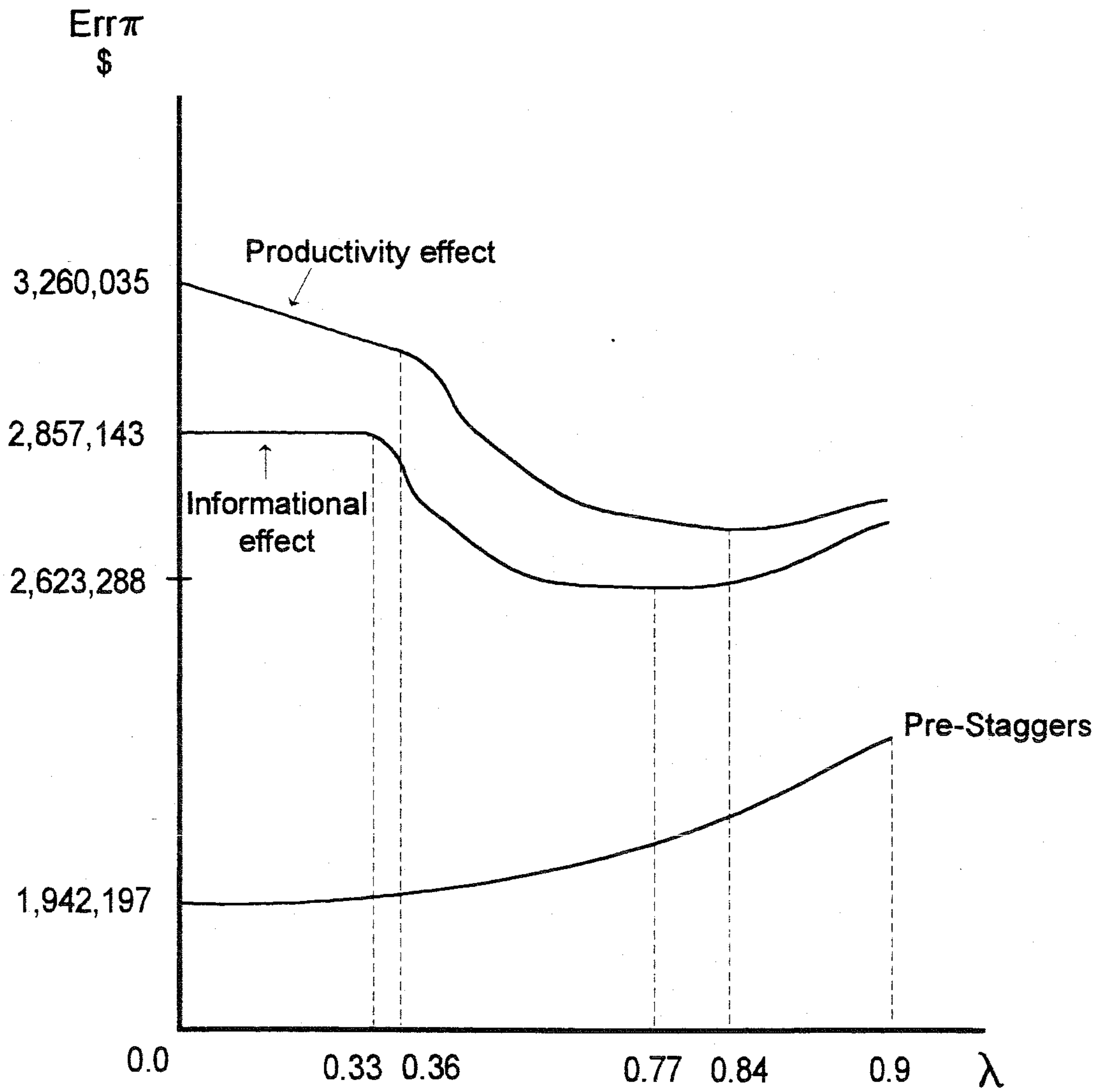

Figure 4. Expected railroad profits under the pre-Staggers system and guaranteed service system.

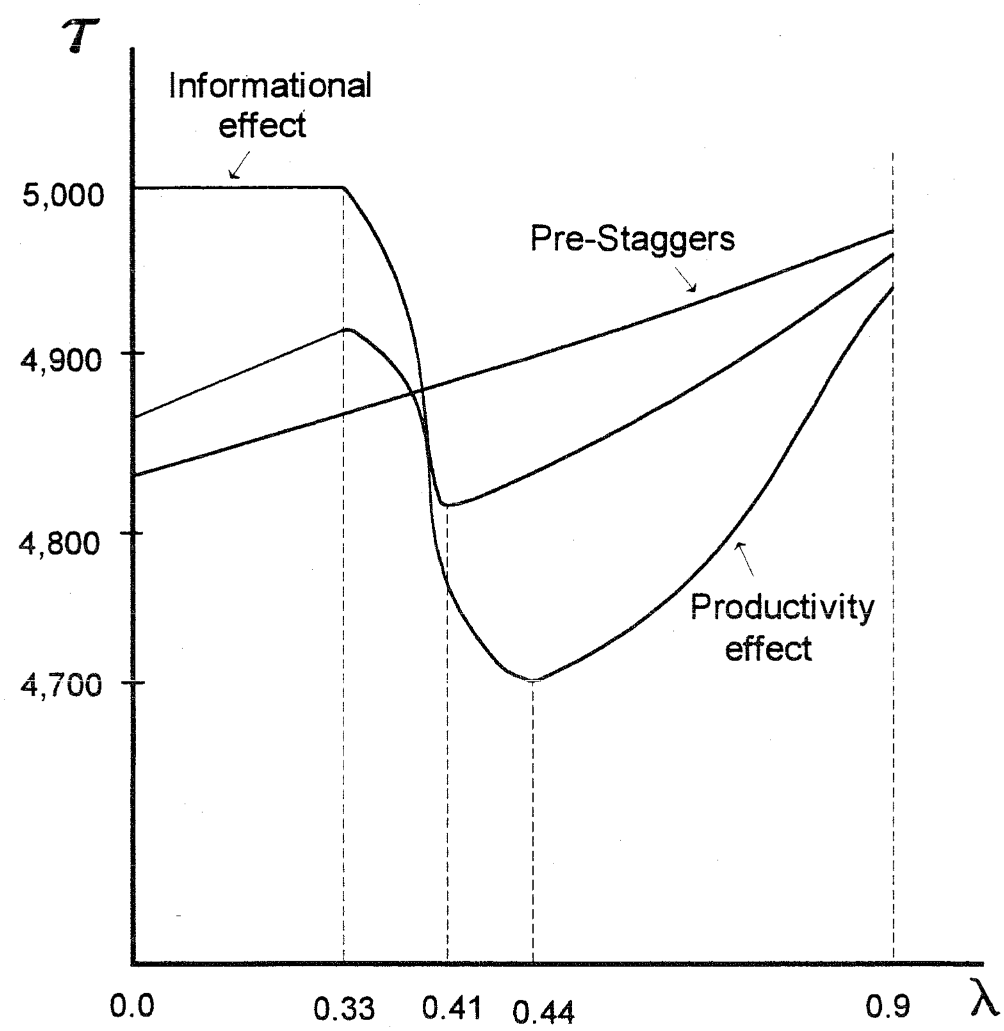

Figure 5. Optimal tariff rate under the pre-Staggers system and guaranteed service system.

An example of the informational effect on railroad capacity is shown in table 2. The railroad acquires a more appropriate capacity level with the additional information provided by guaranteed service. Total railroad capacity is allowed to decrease (increase) when the shipper salvage value is higher (lower) than average. Also, tariff service capacity decreases with the introduction of guaranteed service as shippers substitute guaranteed service for tariff service. In this manner, the lost sales from insufficient capacity and investments in idle equipment are reduced. Hence, expected railroad profit always increases from the informational effect on railroad capacity.

Figure 6 shows that the informational effect of guaranteed service on expected shipper profits depends on whether unit capacity costs are high or low relative to unit operating costs. If unit capacity costs are relatively high ($\lambda<0.4$), shippers are worse off with guaranteed service than under the pre-Staggers system. In these cases, expected shipper profit with guaranteed service is lower than the pre-Staggers level because guaranteed service is offered totally at the expense of tariff service. Shippers lose marketing flexibility when only guaranteed service is produced. In some instances, the tariff rate is higher with guaranteed service than the pre-Staggers tariff rate. This further decreases the expected shipper profit. Shippers, however, are better off with guaranteed service when the railroad offers guaranteed service as well as tariff service. In these cases, capacity costs are relatively low ($\lambda>0.4$) and the railroad decreases its tariff rate from the pre-Staggers rate. Both the lower tariff rate and increased service offerings cause expected shipper profit to increase beyond the pre-Staggers level.

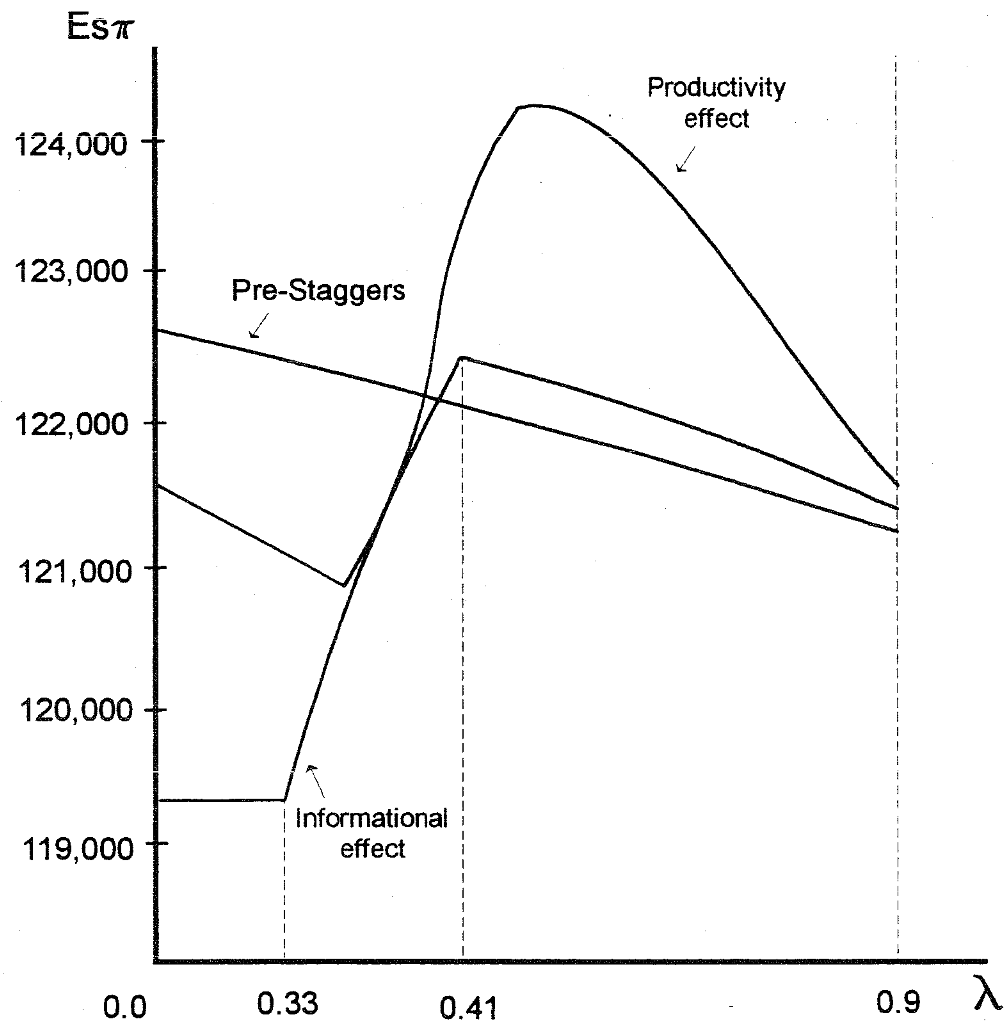

Figure 6. Expected shipper profit under the pre-Staggers system and guaranteed service system.

Table 2. Informational effects of guaranteed service on railroad capacity for λ=0.3, 0.6, and 0.9.

		Post-Staggers capacity			Pre-Staggers
λ	z	Tariff	Guaranteed	Total	capacity
	$5,850	0	1,500	1,500	
0.3	5,950	0	1,429	1,4291,496	
	6,050	0	1,357	1,357	
	5,850	271	1,463	1,734	
0.6	5,950	271	1,392	1,6631,638	
	6,050	271	1,320	1,591	
	5,850	1,096	972	2,068	
0.9	5,950	1,096	900	1,9961,996	
	6,050	1,096	829	1,925	

Figure 7 shows that total welfare, the sum of expected railroad and shipper profits, is higher with guaranteed service than under the pre-Staggers system, regardless of the distribution of capacity and operating costs. If a portion of the railroad gains are transferred to shippers offsetting their losses, all parties are made better off from the informational gains associated with guaranteed service.

Rail Car Productivity Gains

Rail car productivity effects are examined by assuming the trips completed by a car in guaranteed service are 10 percent greater than the trips completed by a car in tariff service, $\theta=(\alpha_n/\alpha_g)=$ (1.5/1.65)=0.91. Figures 4, 6, and 7 also show expected railroad profit, expected shipper profit, and total welfare in the presence of a 10 percent increase in rail car productivity from guaranteeing service.

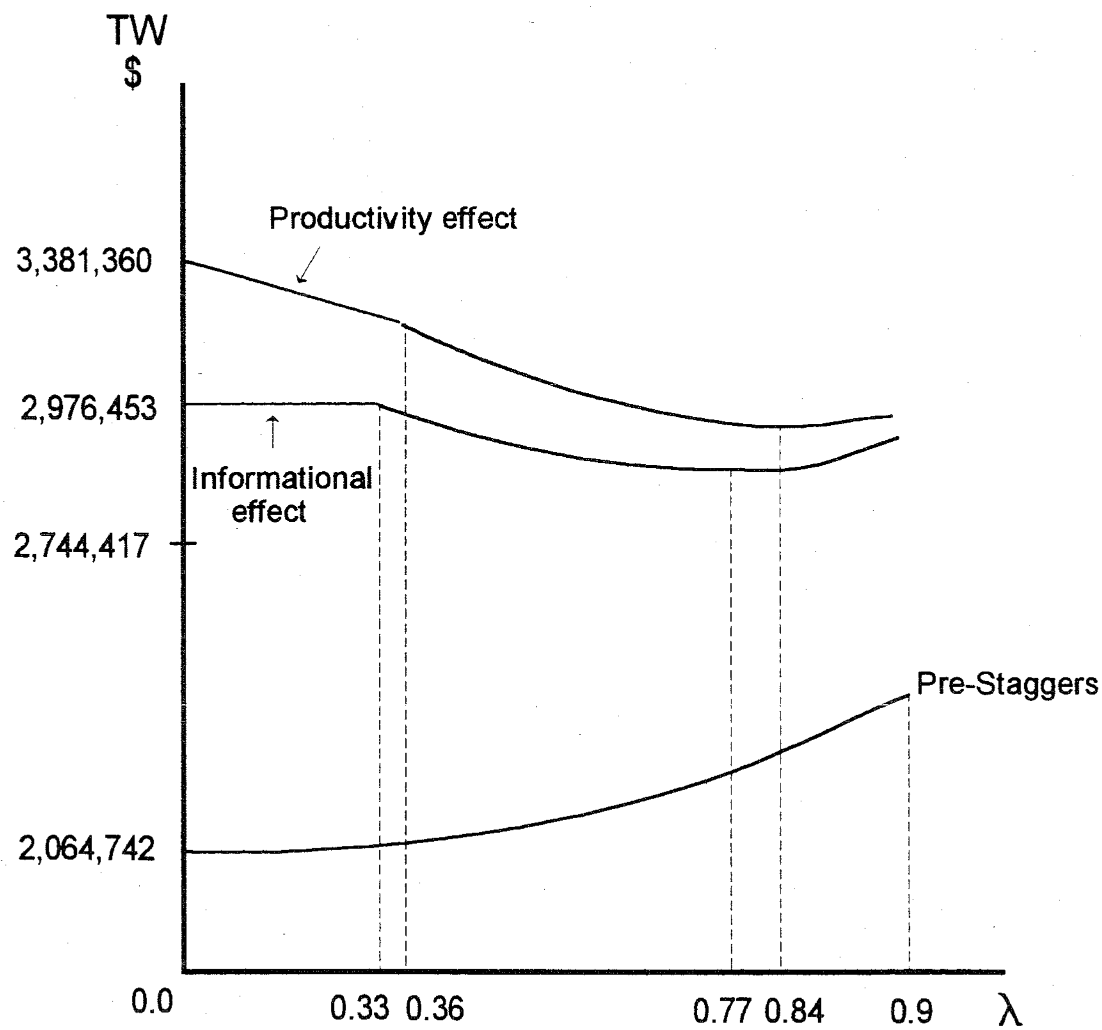

Figure 7. Total welfare under the pre-Staggers system and guaranteed service system.

Expected railroad profits increase and expected shipper profits do not decrease. Hence, total welfare increases due to the rail car productivity gains.

Figure 5 also shows the railroad tariff rate with rail car productivity gains. The railroad decreases its tariff rate except in a few cases. Productivity gains implies the capacity costs per unit of guaranteed service is reduced. A unit of guaranteed service becomes cheaper to produce than a unit of tariff service. Hence, the railroad decreases the tariff rate in order to attract more guaranteed service.

Table 3 provides an example of the tariff service and guaranteed service capacity of the railroad with and without the 10 percent productivity gain. The guaranteed service capacity with productivity gains is always greater than or equal to the capacity without productivity gains. The railroad increases the amount of guaranteed service demanded by decreasing its tariff rate and acquires a larger guaranteed service capacity. Productivity gains also reduce the incentive for the railroad to acquire tariff service capacity. The tariff service capacity decreases and the guaranteed service capacity increases. But the increase in guaranteed service capacity more than offsets the decrease in tariff service capacity, so total railroad capacity increases.

Recall from figure 5 that, in a few cases, the railroad leaves the tariff rate unaltered. The railroad produces the same guaranteed output at the same tariff but at a lower cost. The railroad absorbs the entire efficiency gains from the increased productivity of rail cars in guaranteed service. In these instances, the railroad uses the productivity gains from guaranteeing service to decrease its fleet but leaves total railroad capacity unchanged.

The railroad must serve all requests for guaranteed service therefore, guaranteed service capacity can be represented by guaranteed service demand (G) and the guaranteed service

Table 3. Productivity effects of guaranteed service on railroad capacity for $0.6 \le \lambda \le 0.8$.

		Railroad capacity 10% productivity gain			Railroad capacity zero productivity gain		
λ	z	Tariff	Guaranteed	Total	Tariff	Guaranteed	Total
	$5,650	246	1,671	1,918	271	1,606	1,877
	5,750	246	1,599	1,845	271	1,535	1,806
	5,850	246	1,528	1,774	271	1,463	1,734
0.6	5,950	246	1,457	1,703	271	1,392	1,663
	6,050	246	1,385	1,631	271	1,320	1,591
	6,150	246	1,314	1,560	271	1,249	1,520
	6,250	246	1,242	1,488	271	1,177	1,448
	5,650	441	1,532	1,973	458	1,485	1,943
	5,750	441	1,460	1,901	458	1,413	1,871
	5,850	441	1,389	1,830	458	1,342	1,800
0.7	5,950	441	1,317	1,758	458	1,271	1,729
	6,050	441	1,246	1,687	458	1,199	1,657
	6,150	441	1,174	1,615	458	1,128	1,586
	6,250	441	1,103	1,544	458	1,056	1,514
	5,650	697	1,363	2,060	707	1,334	2,041
	5,750	697	1,292	1,989	707	1,262	1,969
	5,850	697	1,220	1,917	707	1,191	1,898
0.8	5,950	697	1,149	1,846	707	1,119	1,826
	6,050	697	1,078	1,775	707	1,048	1,755
	6,150	697	1,006	1,703	707	977	1,684
	6,250	697	935	1,632	707	905	1,612

fleet by (G/α_g). The tariff service fleet consists of the remaining cars $[R-G/\alpha_g]$ and tariff service capacity is denoted as $\alpha_n[R-G/\alpha_g]=\alpha_n R-\theta G$.

Total capacity of the railroad never decreases with rail car productivity gains but the total fleet size may decrease. The total railroad fleet may be reduced for two reasons. First, the increased rail car productivity allows the amount of cars in guaranteed service to be reduced even though the total amount of guaranteed service capacity increases. Second, the tariff service fleet is reduced, since rail car productivity gains decreases the tariff service capacity. For example with $\lambda=0.8$ and z=$5,650, the guaranteed service capacity is 1,334 and 1,363 units without and with a 10 percent productivity gain from guaranteeing service. The fleet needed to provide these guaranteed service capacities are 889 (1,334/1.5) and 826 (1,363/1.65) cars. The guaranteed service fleet decreased 63 cars even though guaranteed service capacity increased 30 trips. Furthermore, the tariff service fleet also decreases from 472 to 465 cars. Hence, total railroad capacity increases 19 trips from 2,041 to 2,060, while the fleet is reduced 70 cars from 1,361 cars to 1,291 cars. Rail car productivity gains allows the railroad increase the capacity of an existing fleet or increase its capacity while reducing its fleet.

Limiting Guaranteed Service

Currently, railroads limit the amount of guaranteed service offered to shippers. The BN limits the amount of COTs to 40 percent of its projected fleet, while the SOO PERX limit is 25 percent. An auction is used by these railroads to distribute the guaranteed service among shippers. Limiting the supply of guaranteed service increases shipper bids. The UP, which offers guaranteed service at the same rate as tariff service, also restricts the amount of guaranteed service. Each shipper is given an upper limit on the amount of guaranteed service it can acquire. The upper limit is based on a four year historical average of railroad provided cars. The upper limit gives the shippers the incentive to use more rail service (guaranteed and tariff service) to protect their future allocations of guaranteed service. The UP reasoning for such a system is to increase the equity in the distribution of guaranteed service [Machalaba, 1990].

The constraints on guaranteed service appear to be more political than institutional. The Staggers Act stated that a railroad is prohibited from entering into contracts for the transportation of agricultural commodities which utilizes more than 40 percent of its fleet [Goldstein, 1991]. The ICC, however, found the BN COT program not to be a form of contract service and therefore is not bound by such a constraint [Brown, 1992; Cawthorne, 1992]. The purpose of the contracting constraint was to ensure railroads could fulfill their common carrier obligation of providing adequate tariff service to shippers on reasonable request.

Railroads may limit guaranteed service in order to maintain a good working relationship with shippers. Railroads are usually perceived as giant enterprises enjoying a high degree of monopoly power, while farmers and grain shippers operate in highly competitive markets. Consequently, railroad actions attract a great deal of public and political concern and rail executives may well avoid any negative attention [USDOT, 1994]. The self-imposed limit may serve as public relations device to ensure shippers there is enough rail capacity for the railroad to satisfy its common carrier obligation. A smaller guaranteed fleet is perceived by shippers to imply a larger tariff service fleet. The railroad is then perceived as providing adequate tariff service on reasonable request. In this manner, the railroad may avoid possible future law suits concerning its failure to meet its common carrier obligation. For example, the United States Court of Appeals found that in order to conclude whether the Burlington Northern meets its common carrier obligations to shippers, the ICC must determine if the COT program adversely affects the BN's ability to provide equitable and adequate tariff service on reasonable request [United States Court of Appeals, 1993]

The guaranteed service limit will be shown to inhibit the railroad fleet sizing decision. The limit serves to restrict the grain market information flowing from shippers to the railroad when acquiring guaranteed service. The guaranteed service limit causes the tariff service fleet to increase, but the expected railroad and shipper profit decrease.

The two situations studied are shown in table 4 with ϵ=300, and λ=0.3 and 0.5. The shipper salvage value is either $5,650, $5,950, or $6,250. Suppose the amount of guaranteed service each shipper can purchase is limited to 13 units. Hence, the railroad cannot produce more than 1,300 units. In the two situations, the guaranteed service constraint is non-binding during the lowest demand period (z=$6,250) since shippers purchase less than 1,300 units of guaranteed service. In the remaining two demand states (z=$5,950 and $5,650) shippers desire to purchase more than 1,400 units, but are constrained to 1,300 units.

In this example, the railroad is able to identify the low demand period, but is unable to distinguish between the other two demand states. With the constraint the railroad is unable to extract the private shipper salvage information whenever shippers order 1,300 units of guaranteed service.

Table 4 shows the change in the tariff rate, tariff and guaranteed service capacities, expected railroad profits, and expected shipper profits due to the guaranteed service limit of 1,300 units. Expected railroad and shipper profits decreased in response to the limit, while the tariff increased. In each instance, the tariff rate is increased until the amount of guaranteed service in the middle demand state is slightly below the limit. Hence, the railroad is able to identify each state of tariff service demand.

Table 4. Effect of limiting guaranteed service on railroad and shipper expected profit and decisions.

λ	Guar. Limit	Tariff Rate t($)	$Err\pi$ ($)	$Es\pi$ ($)	z ($)	Guar. Capacity	Tariff Capacity	Total Capacity
0.3	1,300	5,167	2,692,985	117,413	5,650	1,300	234	1,534
					5,950	1,299	19	1,318
					6,250	1,086	19	1,105
	None	5,000	2,857,143	119,501	5,650	1,643	0	1,643
					5,950	1,429	0	1,429
					6,250	1,214	0	1,214
0.5	1,300	5,046	2,625,367	119,418	5,650	1,300	406	1,706
					5,950	1,299	192	1,491
					6,250	1,086	192	1,278
	None	4,822	2,744,314	122,456	5,650	1,710	120	1,830
					5,950	1,496	120	1,616
					6,250	1,281	120	1,401

CONCLUSIONS

The movement of grain by the railroad industry has and continues to be plagued by the persistent car shortages and surpluses. Due to these difficulties and other reasons, the Staggers Rail Act of 1980 was passed to help solve these problems. Since the passage, the railroad industry has begun experimenting with different types of rail car ordering systems.

Previous to the Staggers Act, railroads offered only tariff service. In the pre-Staggers system, shippers ordered rail service on a spot basis. Shippers have full information about grain market conditions when ordering tariff service. However, the tariff service order may be rationed.

Recent car ordering systems offer guaranteed service in addition to tariff service. Guaranteed service is ordered by shippers in advance and before possessing full grain market information. However, guaranteed service orders cannot be rationed by the railroad. The railroad uses the guaranteed service orders to make a more informed capacity decision. Furthermore, the advance information concerning demand also allows the railroad to route its assets more efficiently and reduce operating costs. Tariff service is handled in the same manner as the pre-Staggers system.

The models presented in this research are restrictive. The simplified models continue to capture many of the important aspects surrounding guaranteed rail service. The restrictions were necessary to simplify the analysis and to obtain initial results concerning the effects of guaranteeing rail service.

The simplified model representing the pre-Staggers system replicates the persistent existence of car shortages and car surpluses. The railroad choosing its tariff and capacity before knowing demand creates the car shortages and car surpluses. The railroad is assumed to have constant per unit operating costs and constant per unit capacity costs. This problem of a monopolist choosing capacity and price before knowing demand has been discussed previously in the literature.

The post-Staggers model of guaranteed service developed in the model does not replicate either the BN and SOO auction systems nor the UP historical use allocation system. Thus the reader is cautioned in interpreting the results. This study is the first attempt to model the concept of guaranteed rail service and highlight its issues by developing simplified models. The effect of guaranteeing service was divided into the shipper externality, informational effect, and the rail car productivity effect.

The effects of guaranteeing rail service in the world portrayed in these simplified models are:

I) Information obtained by railroads through guaranteed service orders results in improved:
   - Rail car productivity
     The rail car productivity gains of guaranteeing rail service occurs because guaranteed service is purchased in advance giving the railroad advance notice of the specific origin and destination of future movements. With this advanced information, the railroad is able to reduce its car cycle time and increase the productivity of its cars in guaranteed service. Impact of improved rail car productivity on:
     - *Railroads*
       Improved rail car productivity always increases total welfare and expected railroad profit. The improved rail car productivity lowers the unit capacity cost of guaranteed service implying a lower total unit cost of producing guaranteed service.
     - *Shippers*
       Improved rail car productivity either increases or

leaves expected shipper profit unchanged. In almost all cases, the railroad lowers its tariff rate in order to increase the purchase of guaranteed service. Improved rail car productivity lowers the cost of guaranteed service. Expected shipper profit increases due to the lower tariff rate. In a few cases, the tariff rate is unchanged leaving guaranteed service demand unchanged. The railroad uses the productivity gains to lower its cost of producing the same output level. Hence, expected shipper profit does not change.

- *Rail car fleet*
  Improved rail car productivity either increases railroad capacity or leaves it unaltered. However, the fleet size necessary to produce the improved or unaltered railroad capacity may actually decrease. Hence, with improved rail car productivity, comparing the fleet sizes of pre-Staggers systems to current car ordering systems are meaningless when making inferences about shipper welfare.

- Railroad capacity planning
  The informational effect of guaranteeing rail service provides additional grain market information that allows the railroad to make a more informed capacity decision. The impact of improved railroad capacity results in:
  - *Railroads*
    The informational effect always increases total welfare and expected railroad profits. The improved fleet size reduces the likelihood of both railroad investments resulting in idle equipment and lost sales due to the lack of rail cars.
  - *Shippers*
    The informational effect may increase or decrease expected shipper profit. Expected shipper profits decrease when capacity costs are high relative to operating costs. In these cases, the railroad produces only guaranteed service. The railroad increases its tariff rate (from the pre-Staggers

rate) to take advantage of shippers fear of rationing. Tariff service demand and capacity is zero. Despite the increased reliability in rail service, expected shipper profits decrease due to the increased tariff rate and the loss in marketing flexibility. Expected shipper profits increase when capacity costs are low relative to operating costs. The fear of being rationed is not as great and the railroad decreases its tariff rate, enticing shippers to purchase guaranteed service. The railroad is able to lock in business through the reduced tariff. In these cases, expected shipper profit increases due to the lower tariff rate and increased service offerings.

II) Limiting the amount of guaranteed service purchased by shippers.

Currently, railroads limit the amount of guaranteed service shippers may acquire. The reasons for this limit appear to be more political than economic. The limit appears to serve as a public relations device to ensure shippers there is enough rail capacity for it to satisfy its common carrier obligation. A smaller guaranteed service fleet implies a larger tariff service fleet, and thus the better the railroad becomes at providing adequate tariff service at reasonable request.

- Expected profits

  Impact of imposing a guaranteed service limit results in:

  - *Railroads*

    The guaranteed service limit reduces expected railroad profit. However, the railroad may not be exposed to future lawsuits regarding its common carrier obligation.

  - *Shippers*

    The guaranteed service limit decreases expected shipper profit. The limit constrains the purchases of shippers and restricts their opportunities.

- Railroad Decisions

  Impact of imposing a guaranteed service limit results in:

  - *Tariff rate*

    The guaranteed service limit increases the railroad tariff rate. The railroad increases its tariff rate, so that shippers only purchase the guaranteed service limit when the future expected demand for tariff service is high. This allows the railroad to maintain its informational gain when making capacity decisions.
  - *Tariff service capacity*

    The guaranteed service limit increases the tariff service capacity of the railroad. The higher tariff rate and reduced guaranteed service demand increases the incentive for the railroad to acquire a larger tariff service fleet.
  - *Guaranteed service capacity*

    The guaranteed service limit decreases guaranteed service capacity. The higher tariff rate reduces shipper demand for guaranteed service.
  - *Total capacity*

    The guaranteed service limit decreases total railroad capacity. The reduction in guaranteed service exceeds the increase in tariff service capacity.

III) Shipper externality associated with guaranteed service.

The shipper externality is that shippers fail to take into account the effect of their guaranteed car order on the tariff service ration quantity available to all shippers.

- The impact of the shipper externality.

  The externality serves to reduce shipper expected profit.

Suggestions for Further Research

The models presented in this research to study the effects of guaranteed service are restrictive. The restrictions were necessary to simplify the analysis and to obtain initial results concerning the concept of guaranteed rail service. Specifically, the analysis discussed the informational gains associated with guaranteed service which are used by railroads in operational and capacity planning. The analysis also discussed the issues surrounding the shipper decision to purchase guaranteed rail service. Further efforts are needed to make these models more closely parallel real world car allocation systems.

Extensions of the models include a multi-market dynamic model allowing shippers to either sell their grain to many markets or store the grain to sell at a later date. A multi-period model along with restricting the amount of guaranteed service available to shippers to some historical average of purchased rail service more closely resembles the UP historical use program. The extended model could also include alternative modes of transportation or more than one carrier for each mode of transportation. The transportation industry could be modeled an oligopolistic industry with a few large carriers. Alternatively, the dominant firm model could be used to model the transportation industry, with the railroad as the dominant firm and the trucking industry as the competitive fringe.

The model assumed a single price for both tariff and guaranteed service which is representative of the Union Pacific Railroad. However, the Burlington Northern Railroad and Canadian Pacific Soo Line offer guaranteed service through a quasi auction. A model could be formulated allowing different prices for guaranteed service and conventional service. Also, the auction process of allocating guaranteed service could be modeled and the effects of the auction rules on the shipper and welfare be investigated. In this manner, the objections of the NGFA to the BN COT program could be investigated.

The model also assumed each shipper is identical. Each shipper could be assumed to possess different salvage parameters. Hence, the demand for guaranteed and conventional service would differ among shippers. Under these assumptions, the allocation rule used in this research to ration conventional service would be inefficient. Furthermore, if shippers value guaranteed service differently, the process used for rationing a limited supply of guaranteed service would affect the welfare of both the railroad and shippers.

Grain supply is assumed to be constant and homogenous. Shippers, at the time of ordering guaranteed service, may not know how much grain they will have in storage. Supply uncertainty would affect shippers desire for guaranteed service. Similarly, differing the inventory of each shipper would allow the distinction between how small and large shippers are treated by railroads under various car ordering systems.

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