A Game Theory Approach to Railroad-Shipper Negotiations

Game theory provides a framework for analyzing problems when there are a small group of participants. This is unlike the economic model of perfect competition, which requires several participants. Game theory began as a way to analyze parlor card games, but has developed into a rigorous analytical technique for evaluating strategic interactions. These interactions could be between hostile countries, competing companies, or between a shipper and railroad. In fact, game theory provides a useful structure for analyzing the interactions between a shipper and a railroad. This paper models such interactions.

by William Huneke

INTRODUCTION

To frame a problem in game theory terms, the strategies each player might employ must be considered. There is also a need to determine the sequence of play: whether the players interact simultaneously or whether one player moves first and the other reacts. Finally, payoffs each player receives from the interaction of those strategies must be calculated to identify the likely outcome.

Many railroad markets are oligopolistic and economists have used non-cooperative game theory as a tool to model such competition, including Jean Tirole (1989), Dixit and Skeath (1999), and Dutta (2000). However, the model presented in this paper is not based on oligopolistic competition. This paper models the interaction of a monopoly railroad and a captive shipper (i.e., a shipper with no competitive or even oligopolistic options). The railroad monopolist is also assumed to be pricing to maximize its net income from this service.

There have been several papers that have applied game theory to regulatory settings. The problem of access pricing in telecommunications has been studied in several papers, notably Armstrong, Doyle and Vickers (1996), Curien, Julien and Rey (1998), and Laffont and Tirole (1994). These papers have sought to discover a better regulatory pricing paradigm. Another approach has been to model a regulatory agency's interaction with the regulated firm, for example, Baron and Besanko (1984), Laffont and Martimort (1999), and Laffont and Tirole (1986). Finally, Laffont and Tirole (1991) used game theory to study the notion of regulatory capture.

This paper does not model the strategic interaction between the regulated firm and the regulator, nor does it seek to discover a better regulatory pricing paradigm. Instead, it focuses on the negotiation between the regulated firm and its customer and models this negotiation as a strategic game. The regulatory agency's existence provides the customer with a strategic option to litigate the offered rate before the agency. The paper also assumes the current statutory and regulatory framework from which the Surface Transportation Board (STB) operates. It is important to understand shipper-railroad negotiations given the wide latitude for price negotiation provided by the Staggers Act of 1980.

The issue to be analyzed is the strategic interaction between a railroad and a shipper. The railroad provides services that the shipper uses for input to its production. The shipper has alternatives for some of the railroad's services, which could be other modes or even other railroads. However, there are many instances when there are no alternatives. This creates market power for the railroad and has precipitated the implementation of railroad regulation.

The railroad industry exhibits high threshold and fixed costs. This means it exhibits economies of scale, scope and density at high volume levels. Since passage of the Staggers Act in 1980, the industry has been adjusting its capacity to meet industry demand. That means that many markets are served by railroads that have achieved optimal scale, meaning the railroads have exhausted economies and exhibit constant returns. Because railroads have high threshold costs, entry costs are a barrier. This paper allows the shipper to seek entry by another railroad at a cost of a $25 million build-out, which is a figure within the range of a short build-out. The effect of doubling this figure is also considered.

This paper models the railroad-shipper interaction as a game with two players. The railroad moves first and has two strategies: price to avoid litigation or price to maximize profits. In this paper, the railroad's ability to short-run profit maximize is limited by the shipper's ability to access a competitive alternative through a competitive build-out.

In response, the shipper has three strategies:

1. Accept the railroad's offered price
2. Invest (build-out) to achieve access to the nearest competing railroad and gain a competitive price
3. Litigate the offered price at the regulatory agency (Surface Transportation Board).

As a simplification, this paper assumes that if the shipper accepts the railroad's rate, the shipper will sign a contract that locks in that price for a fixed term. A build-out requires the shipper to accept the offered rate for the duration of construction. However, once the build-out is complete, competition between the railroads will drive rates down to marginal cost. Litigation requires the regulatory agency to determine if the offered rate exceeds a rate reasonableness standard.

This paper develops a model of this type of regulatory interaction. The model provides a tool to analyze the decisions of two parties. The railroad aims to maximize its profits. The shipper wants to minimize its costs. The railroad offers a rate and then the shipper chooses to either accept the price, build-out to gain competitive entry, or litigate at the regulatory agency. The model is used to analyze a series of different cost assumptions on each strategy.

THE GAME

In this instance the game is the strategic interaction between a railroad and a shipper. The railroad provides transportation services, and the shipper purchases transportation services to move a load from an origin to a destination. This paper hypothesizes that the shipper is moving coal from a mine to a power plant. Some shippers have numerous alternatives, such as truck carriage, water transport, or even other railroads. However, there are many times when neither the origin nor destination has an economic alternative to rail service. This creates market power for the railroad, which is the premise for the implementation of railroad regulation in the United States.

This paper hypothesizes that the railroad has two basic strategies: price to maximize profits or price to avoid litigation. Consider first the profit maximizing strategy. If the shipper's only competitive alternative is a build-out to another railroad, the railroad will charge a rate just below the level that gives the shipper the incentive to build-out to another railroad. The paper assumes this rate is 5% less than the rate at which the shipper is indifferent to a build-out. On the other hand, if the railroad wants to avoid litigation, it must set its rate below what it estimates the STB will determine to be the regulatory rate ceiling. As a simplification, this paper assumes the STB will find that the regulatory rate ceiling to be 180% of URCS, the Uniform Railroad Costing System, which is the Board's program for variable costs of a railroad movement. U.S. law 49 U.S.C. 10707(d)(1)(A) limits the Board's ability to prescribe rates less than 180% of URCS cost. The Board could find during litigation that a challenged rate exceeded Stand Alone Cost (SAC), which was higher than 180% of URCS variable cost. For simplicity, this paper ignores that possibility.

This paper assumes the railroad will offer a rate that is 5% below the regulatory ceiling to clearly signal to the shipper that the railroad wants to avoid litigation. To complete the game's structure, it seems reasonable to assume that the railroad moves first. It offers a rate and the shipper reacts. To complete the analysis, the model must include an estimate of the payoffs for each of the game's six possible outcomes.

THE MODEL

The game's six payoffs are:

- Parties contract at the railroad's profit maximizing (PM) rate
- Parties contract at the railroad's litigation avoidance (LA) rate
- Railroad offers PM rate, and shipper builds out to another railroad
- Railroad offers LA rate, and shipper builds out to another railroad
- Railroad offers PM rate, and shipper litigates
- Railroad offers LA rate, and shipper litigates

In each calculation marginal cost is subtracted from the revenues that change hands. This paper assumes that marginal cost is the proxy for the incremental economic costs of providing the service. Any costs beyond marginal costs, such as build-out construction costs or litigation costs, will be added or subtracted as appropriate. Litigation costs occur in the first year and are not discounted. Because the build-out costs are assumed to occur over a two-year period, the second year is discounted. The calculations will show payoffs in terms of shipper costs or railroad net income from this service. The calculations are described first and then the actual equations are presented.

Calculations

PM Rate: The rate the railroad can charge to make a positive net income from this service but still deter a build-out is determined first. This requires calculating a rate that produces railroad net income that is less than the shipper's costs of a build-out. These are calculated as present values.

Contract & PM Rate: From society's standpoint this outcome has modest appeal. It avoids third party intervention that necessarily occurs in either a build-out or litigation. For one thing, a build-out requires more regulatory intervention in the form of an environmental analysis by the STB. The cost payoff to the shipper is the present value of revenues paid above marginal cost summed over the contract's term. This case is simply an income transfer so the railroad's increased net income from this service equals the shipper's costs.

Contract & LA Rate: This outcome has a bit more societal appeal because it avoids third party intervention and yet yields a lower rate to the shipper, a rate closer to incremental economic costs. The calculation is the same as the previous case, although the rate and revenues will be different. The cost payoff to the shipper is the present value of revenues paid above marginal cost summed over the contract's term. This case is also simply an income transfer so the railroad's positive net income equals the shipper's costs.

Build-out & LA Rate: This is a bad outcome for the railroad. Generally the LA rate will be below the PM rate, but the railroad still faces increased competition due to the build-out. The railroad earns just the present value of the net income during the build-out period. After that, competition drives rates to marginal cost. This is a reasonable assumption based upon the railroad industry's optimized unit train coal service (i.e., a homogeneous service at most efficient scale). Also, Grimm and Winston (2000, p. 65) found that captive shippers pay freight rates that are 21% higher than those paid by non-captive shippers. Thus, the intra-railroad competition resulting from the build-out will push rates toward marginal cost. The shipper's costs are the railroad's net income from this service during the build-out period plus the costs of the build-out.

Build-out & PM Rate: The calculation here is similar to the previous outcome except that the railroad's net income from this service is based on the PM rate instead of the LA rate.

Litigate & PM Rate: In this outcome it is assumed that the shipper wins the litigation case and the STB prescribes a rate. Because the lowest rate the STB can prescribe is 180% of URCS variable cost, for purposes of this analysis we will make a further simplifying assumption that the prescribed rate equals 180%. (It is possible that the STB would set the rate at SAC, but assuming that the STB simply sets the rate at the regulatory threshold makes the analysis tractable and makes this option more favorable to the shipper.) For simplicity it is also assumed that marginal cost and URCS variable cost are equal. While URCS estimates do not necessarily represent marginal economic costs, they are plausible estimates of average variable costs. Average variable costs would equal marginal costs if the railroad had achieved optimal scale. The prescribed rate holds for the entire period under consideration because the railroad will pay the shipper the present value of any overcharges. The railroad's payoff is its net income from this service, which is the present value of the capped revenues minus marginal cost during the period, further reduced by the litigation expenses. The shipper's payoff is the railroad's economic costs plus the shipper's litigation expenses.

Litigate & LA Rate: For this outcome it is assumed that the railroad wins the litigation and the Board finds the rate reasonable. This payoff is similar to *Contract & LA rate* except litigation expenses are added to shipper costs and deducted from railroad profits.

The variables used in the payoff equations are defined as follows:

C	Cost of build-out to another railroad
PMR	Profit maximizing rate, LP*0.95
F	Litigation expense for shipper
LAR	Litigation avoidance rate
H	Litigation expense for railroad
i	Interest rate
LP	Limit Price, rate that makes shipper indifferent to building out
MC	Long run marginal cost
m	Number of periods of build-out construction
n	Contract length in years
RM	Regulatory markup over MC (80%)
S	Shipment size

Equations

(1) To calculate LP:

$$0 = \sum_{0}^{m}\left(\frac{C/m}{(1+i)^{m}}\right) - \sum_{n-m}^{n}\left(\frac{LP-MC}{(1+i)^{n}}\right) * S_n$$

Calculations of Shipper Costs:

Event: ***Equation:***

(2) Contract at LAR $\sum_{0}^{n}\left(\frac{LAR-MC}{(1+i)^{n}}\right) * S_n$

(3) Contract at PMR $\sum_{0}^{n}\left(\frac{PMR-MC}{(1+i)^{n}}\right) * S_n$

(4) Build-out & LAR

$$\sum_{0}^{m}\left(\frac{\left[C/m\right]+\left[LAR-MC\right]}{\left[1+i\right]^{m}}\right) * S_n$$

(5) Build-out & PMR

$$\sum_{0}^{m}\left(\frac{\left[C/m\right]+\left[PMR-MC\right]}{\left[1+i\right]^{m}}\right) * S_n$$

(6) Litigate & LAR

$$F + \sum_{0}^{n}\left(\frac{LAR-MC}{(1+i)^{n}}\right) * S_n$$

(7) Litigate & PMR

$$F + \sum_{0}^{n}\left(\frac{RM*\left[MC\right]}{(1+i)^{n}}\right) * S_n$$

Calculations of Railroad Net Income from This Service:

Event: ***Equation:***

(8) Contract at LAR $\sum_{0}^{n}\left(\frac{LAR-MC}{(1+i)^{n}}\right) * S_n$

(9) Contract at PMR $\sum_{0}^{n}\left(\frac{PMR-MC}{(1+i)^{n}}\right) * S_n$

(10) Build-out & LAR $\sum_{0}^{m}\left(\frac{LAR-MC}{(1+i)^{m}}\right) * S_n$

(11) Build-out & PMR $\sum_{0}^{m}\left(\frac{PMR-MC}{(1+i)^{m}}\right) * S_n$

(12) Litigate & LAR $-H + \sum_{0}^{n}\left(\frac{LAR-MC}{(1+i)^{i}}\right) * S_n$

(13) Litigate & PMR $-H + \sum_{0}^{n}\left(\frac{RM*MC}{(1+i)^{n}}\right) * S_n$

Base Case

To estimate the model, some assumptions are made for the parameter values faced by each player. These assumptions are based upon the author's experience analyzing rate cases at the STB. These assumptions are not drawn from any specific case and are meant to be illustrative. After the results are calculated, they are analyzed using a decision tree. The decision tree will start with the railroad's move followed by branches for each of the shipper's reactions. Each branch will have a payoff for the railroad and shipper.

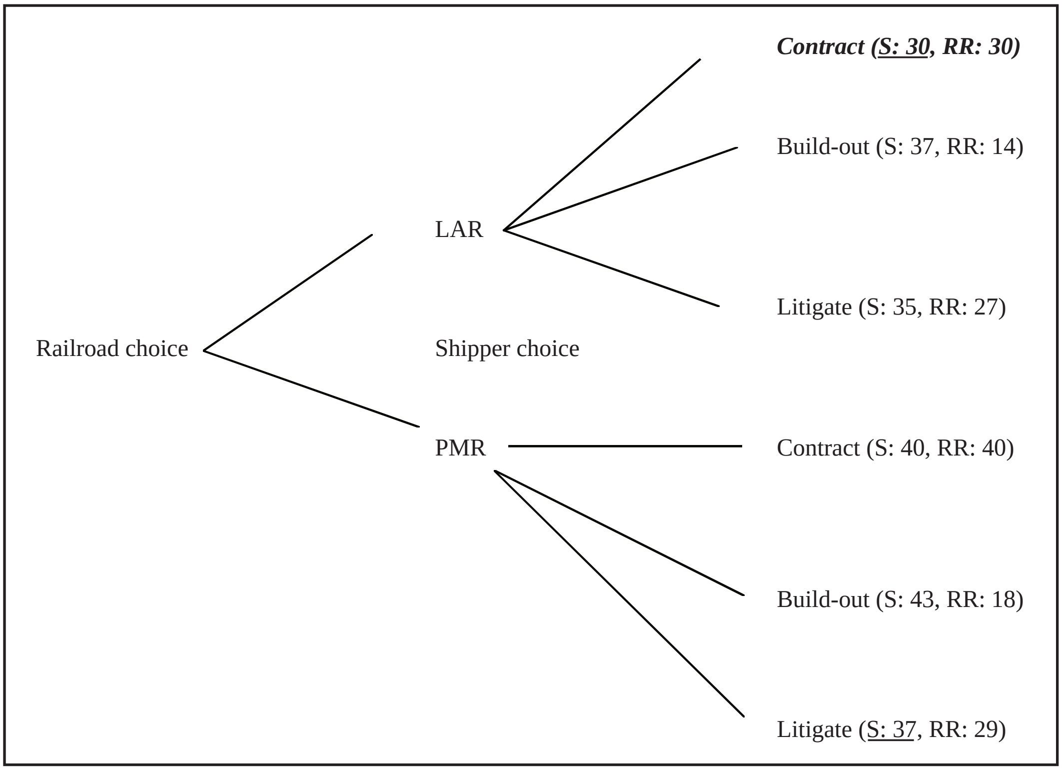
This paper assumes that the railroad will employ a maximin approach. When the railroad considers its first move, it will also consider what will be the shipper's likely reaction. The shipper's payoffs are costs, which the shipper will want to minimize. The railroad will consider as a result of its choice which branch has the lowest cost for the shipper and will choose accordingly.

Here are the base case assumptions:

Build-out cost (C)	$25 million
Build-out period (m)	2 years
Contract term (n)	5 years
Shipment size (S)	1 million tons
PM rate (calculated)	$19.53/ton
Shipper litigation expense (F)	$4 million
Railroad litigation expense (H)	$4 million
Interest rate (i)	10%
Marginal cost (MC)	$10 per ton

Figure 1 shows the decision tree populated with the results from calculations from inserting the base case numbers into the shipper and railroad equations. The payoffs are in millions of dollars. When the railroad reviews its option to charge an LAR (litigation avoidance rate), it sees that the shipper will choose to contract because that's the lowest shipper cost of the three outcomes. This outcome means $30 million in net income from this service to the railroad. If the railroad were to charge a PM rate, then the shipper will choose to litigate. This outcome means $29 million in net income

Figure 1: Base Case Decision Tree



from this service to the railroad. The railroad chooses to set an LAR rate and the outcome is a contract.

EXTENSIONS OF THE MODEL

To extend the model, a few of the base case assumptions are altered. This also allows some analysis of how changing various parameters might affect railroad and shipper decisions to contract, litigate, or build-out. The first assumption to adjust is shipment size, which will be doubled, while keeping all other base case values unchanged (Figure 2).

Double the Shipment Size

When the shipment size is doubled, there are obviously more tons. Two million tons is now substituted in Equation 1. Because there are more tons, the PMR falls to $14.51/ton. This rate is below the assumed regulatory ceiling of 180% of variable cost or $18.00/ton so litigation would fail. If the railroad tried to charge more than $15.28 (where the shipper is indifferent to a build-out), the shipper would build-out.[1] (See Appendix for calculation of both $14.51 and $15.28.) The LAR is above $15.28 so the shipper would choose to build out, which leaves railroad net income at $27 million. Seeing that result, the railroad offers PMR and the party's contract, resulting in $37 million for both parties (Figure 3).

Double Build-out Cost from $25 Million to $50 Million

Increasing the cost of the build-out is equivalent to making the shipper more dependent on the railroad (i.e., "more captive"). In this extension it is still assumed that the shipment size is two million tons. The LA rate is below 180% of variable cost because the railroad is signaling its intention to avoid litigation by offering a rate that is 95% of the regulatory threshold. The railroad selects PMR and the shipper chooses to litigate because the difference between a rate at 180% of variable cost that would be set by the Board during litigation and the LA rate compensates the railroad for litigation expenses.

A More Aggressive Pricing Policy

Consider what happens if the railroad takes a more aggressive stance. Instead of clearly setting its rate below the regulatory threshold, the railroad priced above the regulatory threshold, but just below the point where the shipper would do better by bringing a rate case to the STB. This becomes true up to rate of $18.95/ton. Figure 4 shows what the payoffs to the shipper and railroad would be now.

The railroad chooses the branch that yields it a payoff of $37 million.

Regulatory Agency Perceived As Arbitrary

If the regulatory agency is perceived as arbitrary, the parties perceive that the agency may find an "unreasonable" rate to be "reasonable" and vice versa. For example, the parties could perceive that the agency might incorrectly set a rate below the statutory threshold. This is captured by a new term, IRM. This paper assumes IRM is 75% of the regulatory threshold and represents a rate ceiling of 136% of URCS variable costs instead of 180%. The shipper could anticipate possible gains if it perceives the agency might set a rate at 136% of the regulatory threshold. On the other hand, the railroad would perceive possible gains if it thought it could achieve profit gains from "unreasonable" rates being found "reasonable." To model a situation in which the parties perceive agency decisions as arbitrary, we need to alter the four equations that calculate payoffs to litigation. We add a new factor "*p*", defined as the probability that the agency makes a rational decision (i.e., sets the rate ceiling at 180% of URCS variable costs). In previous examples this "*p*" is assumed equal to one. In the discussion that follows "*p"* is equal to 0.5. The new equations are:

Figure 2: Decision Tree When Shipment Size Doubles

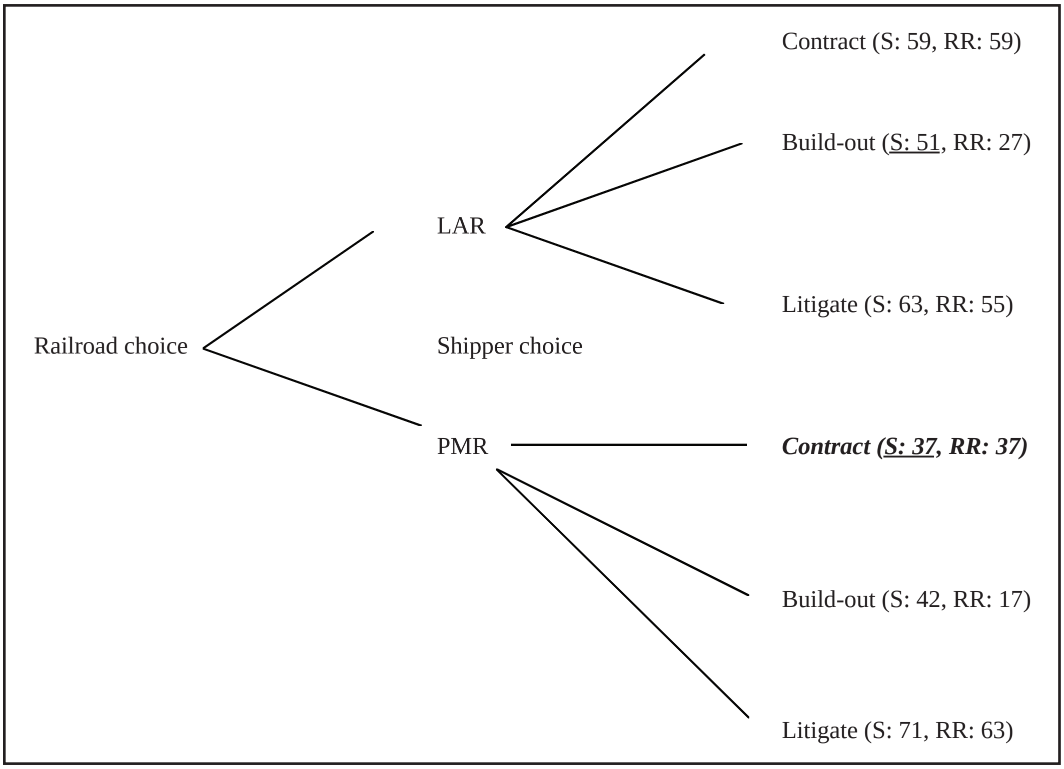


Figure 3: Decision Tree When Build-out is Doubled to $50 Million

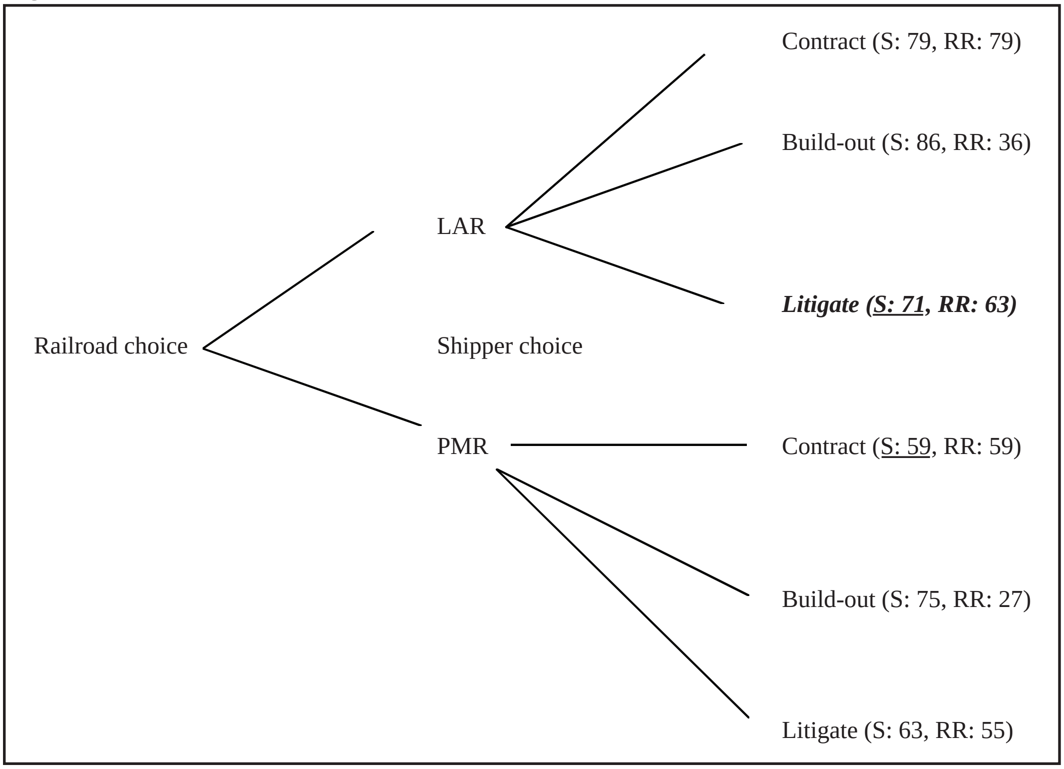
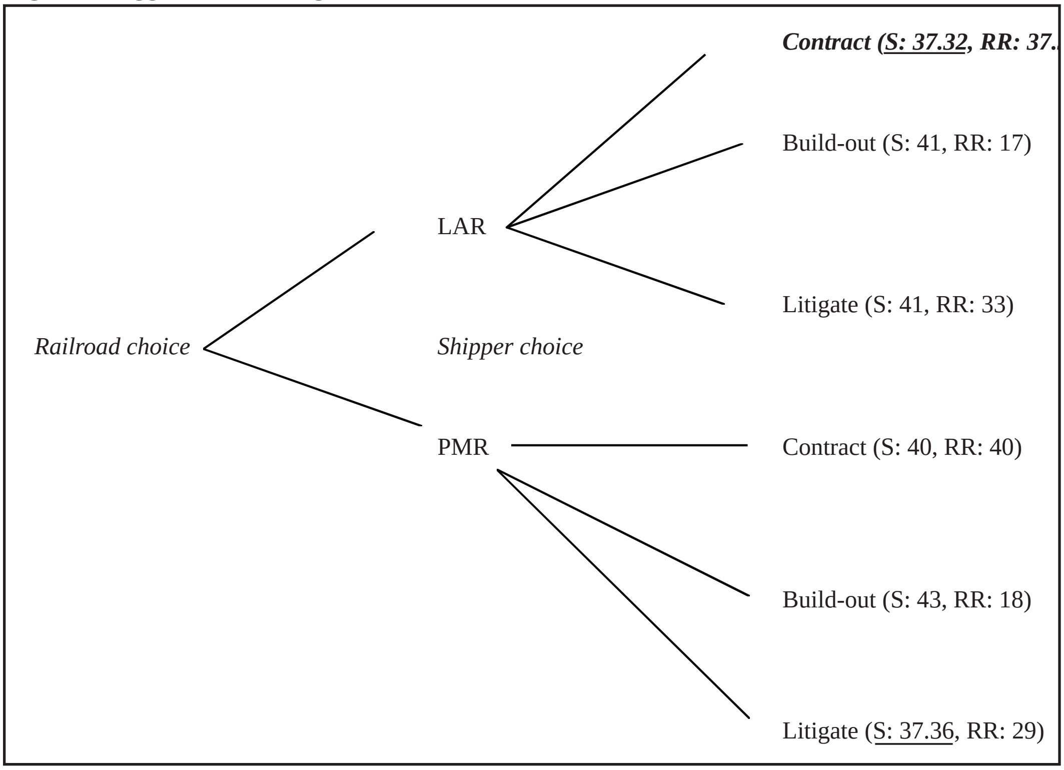


Figure 4: Aggressive Pricing



Event:	***Equation:***
(14) Shipper cost if LAR & litigate	$F+\left(p*\left(\sum_{0}^{n}\left[\frac{LAR-MC}{(1+i)^{n}}\right]*S\right)\right)+\left(\{1-p\}*\left(\sum_{0}^{n}\left[\frac{IRM*MC}{(1+i)^{n}}\right]*S\right)\right)$
(15) Shipper cost if PMR & litigate	$F+\left(p*\left(\sum_{0}^{n}\left[\frac{RM*MC}{(1+i)^{n}}\right]*S\right)\right)+\left(\{1-p\}*\left(\sum_{0}^{n}\left[\frac{PMR-MC}{(1+i)^{n}}\right]*S\right)\right)$
(16) Railroad profit if LAR & litigate	$-H+p*\left(\sum_{0}^{n}\left[\frac{LAR-MC}{(1+i)^{n}}\right]*S\right)+\{1-p\}*\left(\sum_{0}^{n}\left[\frac{IRM*MC}{(1+i)^{n}}\right]*S\right)$
(17) Railroad profit if PMR & litigate	$-H+p*\left(\sum_{0}^{n}\left[\frac{RM*MC}{(1+i)^{n}}\right]*S\right)+\{1-p\}*\left(\sum_{0}^{n}\left[\frac{PMR-MC}{(1+i)^{n}}\right]*S\right)$

Figure 5 allows review of the railroad's analysis of shipper reactions with a perceived arbitrary regulatory agency. In this case, the shipper litigates with either railroad rate strategy. However, the railroad has a better profit opportunity if it profit maximizes. In that case, the railroad believes it can earn a $35 million profit if the shipper chooses its cheapest alternative, litigation. In this case, the railroad believes it has the chance of reaping a windfall gain because it perceives that there is a possibility that the agency will decide in its favor despite the railroad's imposing an exorbitant rate. Thus, an agency that is perceived as arbitrary increases the amount of litigation because both parties have expectations of windfall gains from litigation.

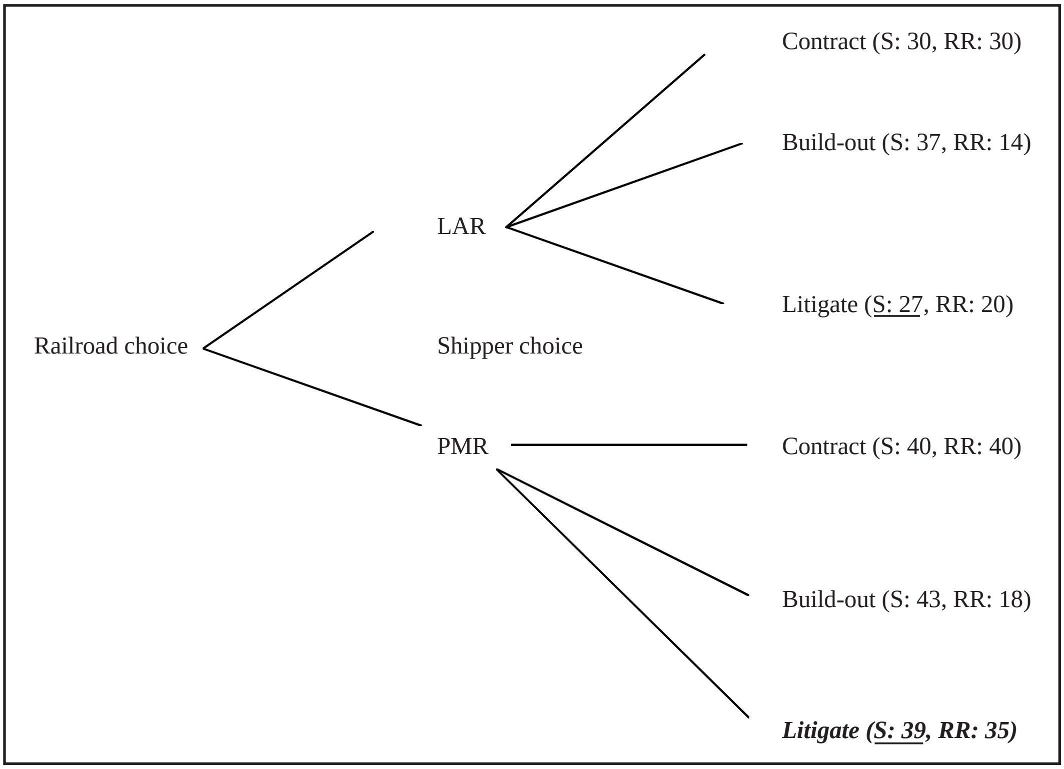
CONCLUSION

The model provides a tool to analyze the decisions of two parties in a railroad-shipper negotiation setting. The seller of services, in this case the railroad, aims to maximize its profits. The buyer, in this case the shipper, wants to minimize its costs. The railroad offers a rate and the shipper chooses to either accept the rate, build-out to gain competitive entry, or litigate at the regulatory agency. A few observations are pertinent after estimating the model.

Larger shipment sizes increase the value of a potential build-out so the parties have incentive to contract with larger shipment sizes. The railroad wants to avoid competitive entry and the shipper gets to avoid unnecessary litigation. On the other hand, increasing the cost of a build-out increases the incentives for litigation. Railroads have less competition to hold down rates and shippers with extremely limited competitive options are more likely to contest rates.

Finally, increased litigation is also the result of the model's extension simulating the parties' perception that the agency has become arbitrary rather than rational or fair. Without a predictable result, the parties have more of an incentive to

Figure 5: Decision Tree When Regulatory Agency Perceived as Arbitrary



"roll the dice" on litigation rather than contract because they perceive an arbitrary agency may provide windfalls. This is an important result that stresses the need for a regulatory agency to be more transparent and predictable in its results in order to reduce unnecessary litigation and encourage private sector solutions.

The model presented in this paper might be extended to analyze repeated games and mixed strategies. This might be a better approach to analyzing the negotiating interaction between a railroad and a shipper. A model of repeated interactions would not view the game as one play but a series of plays as the players negotiate contracts or litigate over several years and often for several different plants and coal mines.

Appendix

To calculate the rate at which the shipper is indifferent to a build-out with a shipment of two million tons: From Equation (1):

$$0 = \sum_{0}^{m}\left(\frac{C/m}{(1+i)^{m}}\right) - \sum_{n-m}^{n}\left(\frac{PMR-MC}{(1+i)^{n}}\right) * S_{n}$$

$$0 = \$12,500,000 + (\$12,500,000/1.10) - ((PMR' - \$10)/(1.10)^{2}) * 2,000,000 + ((PMR' - \$10)/(1.10)^{3}) * 2,000,000 + ((PMR' - \$10)/(1.10)^{4}) * 2,000,000$$

PMR' = \$ 15.28, where PMR' is the rate at which the shipper is indifferent to a build-out.
PMR is then:
0.95 * \$15.28 = \$14.51

References

Armstrong, Mark, Chris Doyle, and John Vickers. "The Access Pricing Problem." *The Journal of Industrial Economics* (1996): 131-150.

Baron, David P. and D. Besanko. "Regulation, Asymmetric Information, and Auditing." *RAND Journal of Economics* 15(4), (1984): 447-470.

Curien, Nicolas, Bruno Jullien, and Patrick Rey. "Pricing Regulation under Bypass Competition." *RAND Journal of Economics* (1998): 259-279.

Dixit, Avinash K. and Susan Skeath. *Games of Strategy*. New York, 1999.

Dutta, Prajit K. *Strategies and Games: Theory and Practice.* Cambridge, MA, 2000.

Grimm, Curtis and Clifford Winston. "Competition in the Deregulated Railroad Industry: Sources, Effects, and Policy Issues." S. Peltzman and C. Winston eds. *Deregulation of Network Industries,* Washington, D.C.: Brookings Institution (2000): 41-72.

Laffont, Jean-Jacques and David Martimort. "Separation of Regulators against Collusive Behavior." *RAND Journal of Economics* (1999): 232-262.

Laffont, Jean-Jacques and Jean Tirole. "Using Cost Observation to Regulate Firms." *Journal of Political Economy* 94(3), (1986): 614-641.

Laffont, Jean-Jacques and Jean Tirole. "The Politics of Government Decision-Making: A Theory of Regulatory Capture." *Quarterly Journal of Economics* (1991): 1089-1127.

Laffont, Jean-Jacques and Jean Tirole. "Access Pricing and Competition," *European Economic Review* (1994): 1673-1710.

Tirole, Jean. *The Theory of Industrial Organization.* Cambridge, MA, 1989.

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