A Refined Game Theory Approach to Railroad-Shipper Negotiations

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Railroad & Shipper Negotiations in the U. S.:

A Game Theory Approach

Abstract: 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.

To frame a problem in game theory terms, we must consider what strategies each player might employ. We also need to determine the sequence of play: whether the players interact simultaneously or whether one player moves first and the other reacts. Finally, we must calculate payoffs each player gets from the interaction of those strategies to identify the likely outcome.

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.

We can frame the railroad-shipper interaction as a game with 2 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 re-source its transportation through a competitive build-out.

In response, the shipper has 3 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, we can say 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 agency to determine if the offered rate exceeds a rate reasonableness standard.

The 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.

I. Introduction

Monopoly and oligopoly market structures are appropriate for analyzing the North American railroad industry. Game theory provides a framework for analyzing monopolistic and oligopolistic market structures. Game theory developed as a method 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 buyer and supplier. As such, game theory provides a useful structure for analyzing the interactions between a shipper and a railroad within the context of United States Surface Transportation Board (STB) regulation.

Game theory requires us to identify the players and what strategies they have available. Sequence of play is important: whether the players interact simultaneously or whether one player moves first and the other reacts. Finally, the payoffs for each player from the interaction of those strategies must be calculated to identify the likely outcome.

II. 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 so it can move a load from an origin to a destination. This paper hypothesizes that the shipper could be 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.

We can frame the railroad-shipper interaction as a game with 2 players. Ignoring those instances in which a shipper can avoid some of the adverse effects of higher rail rates by shifting production to more favored plants or other fuels, this paper examines a game in which the shipper has 3 strategies:

1. Accept the railroad's offered rate
2. Build-out to the nearest competing railroad and gain a competitive rate
3. Litigate the offered rate at the STB

As a further simplification, we can say that if the shipper accepts the railroad's rate, the shipper will sign a contract that locks in that rate 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. Litigating at the STB requires the agency to determine if the offered rate exceeds the Board's rate reasonableness standard.[1]

This paper hypothesizes that the railroad has 2 basic strategies: price to maximize profits or price to avoid litigation. Consider first the profit maximizing strategy. If the shipper's only

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[1] My approach embodied in the model presented has benefitted from reviewing Avinash K. Dixit and Barry J. Nalebuff, *Thinking Strategically: The Competitive Edge in Business, Politics, and Everyday Life* (New York: 1991); Prajit K. Dutta, *Strategies and Games:Theory and Practice* (Cambridge, MA: 2000); Avinash K. Dixit and Susan Skeath, *Games of Strategy*, (New York:

competitive alternative is a build-out to another railroad, the railroad will charge a rate just below the level that incents the shipper to build-out. 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. Adopting this strategy, the railroad will offer a rate that is 5% below the regulatory ceiling. As a simplification, this paper assumes the STB will find that the regulatory rate ceiling to be 180% of URCS. [2]

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, we need to estimate the payoffs for each of the game's 6 possible outcomes.

III. The Model

The game's 6 payoffs are:

- Parties contract at the railroad's profit maximizing (PM) rate
- Parties contract at the railroad's litigation avoidance (LA) rate

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1999).

[2] United States statutes limit the Board's ability to prescribe rates to lower than 180% of URCS cost. 49 U.S.C. 10707(d)(1)(A). 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. URCS is the Uniform Railroad Costing System, which is the Board's program for variable costs of a railroad movement.

- Railroad offers PM rate, and shipper builds out
- Railroad offers LA rate, and shipper builds out
- Railroad offers PM rate, and shipper litigates
- Railroad offers LA rate, and shipper litigates

In each calculation we will subtract marginal cost 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. The calculations will show payoffs in terms of shipper costs or railroad economic profits. First, I describe the calculations and then I present the actual equations.

Calculations

PM rate: First, we must determine the rate the railroad can charge to make an economic profit but still deter a build-out. This requires calculating a rate that produces railroad economic profits that are less than the shipper's costs of a build-out. I calculate these 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 economic profits equal 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 economic profits equal 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 has still gotten the build-out. The railroad just earns the present value of the economic profits during the build-out period. (After that competition drives rates to marginal cost.) The shipper's costs are the railroad's economic profits 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 economic profits are based on the PM rate instead of the LA rate.

Litigate & PM: In this outcome we will assume 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%. (We also make an assumption that marginal cost and URCS variable cost are equal.) The prescribed rate holds for the entire period under consideration because the railroad will pay the shipper the present value of any over-charges. The railroad's payoff is its economic profits, which are 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: For this outcome we assume 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.

In what follows:

C	cost of build-out
PMR	Profit maximizing rate, rate that deters a build-out minus $1/ton (EDR-1)
F	litigation expense for shipper
LAR	Litigation avoidance rate
H	litigation expense for railroad
i	interest rate
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

To calculate PMR:

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

Calculations of shipper costs:

Event:	***Equation:***
Contract at LAR	$\sum_{0}^{n}\left(\frac{LAR - MC}{(1+i)^{n}}\right) * S_n$
Contract at PMR	$\sum_{0}^{n}\left(\frac{PMR - MC}{(1+i)^{n}}\right) * S_n$
Build-out & LAR	$\sum_{0}^{m}\left(\frac{[C/m] + [LAR - MC]}{[1+i]^{m}}\right) * S_n$
Build-out & PMR	$\sum_{0}^{m}\left(\frac{[C/m] + [PMR - MC]}{[1+i]^{m}}\right) * S_n$
Litigate & LAR	$F + \sum_{0}^{n}\left(\frac{LAR - MC}{(1+i)^{n}}\right) * S_n$
Litigate & PMR	$F + \sum_{0}^{n}\left(\frac{RM * [MC]}{(1+i)^{n}}\right) * S_n$

Calculations of Railroad Economic Profits

Event	*Equation:*
Contract at PMR	$\sum_{0}^{n}\left(\frac{PMR - MC}{(1+i)^{n}}\right) * S_{n}$
Contract at LAR	$\sum_{0}^{n}\left(\frac{LAR - MC}{(1+i)^{n}}\right) * S_{n}$
Build-out & PMR	$\sum_{0}^{m}\left(\frac{PMR - MC}{(1+i)^{m}}\right) * S_{n}$
Build-out & LAR	$\sum_{0}^{m}\left(\frac{LAR - MC}{(1+i)^{m}}\right) * S_{n}$
Litigate & LAR	$-H + \sum_{0}^{n}\left(\frac{LAR - MC}{(1+i)^{i}}\right) * S_{n}$
Litigate & PMR	$-H + \sum_{0}^{n}\left(\frac{RM * MC}{(1+i)^{n}}\right) * S_{n}$

Base Case

To exercise the model, we will make some assumptions for each player. After we have calculated the results, we analyze them 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.

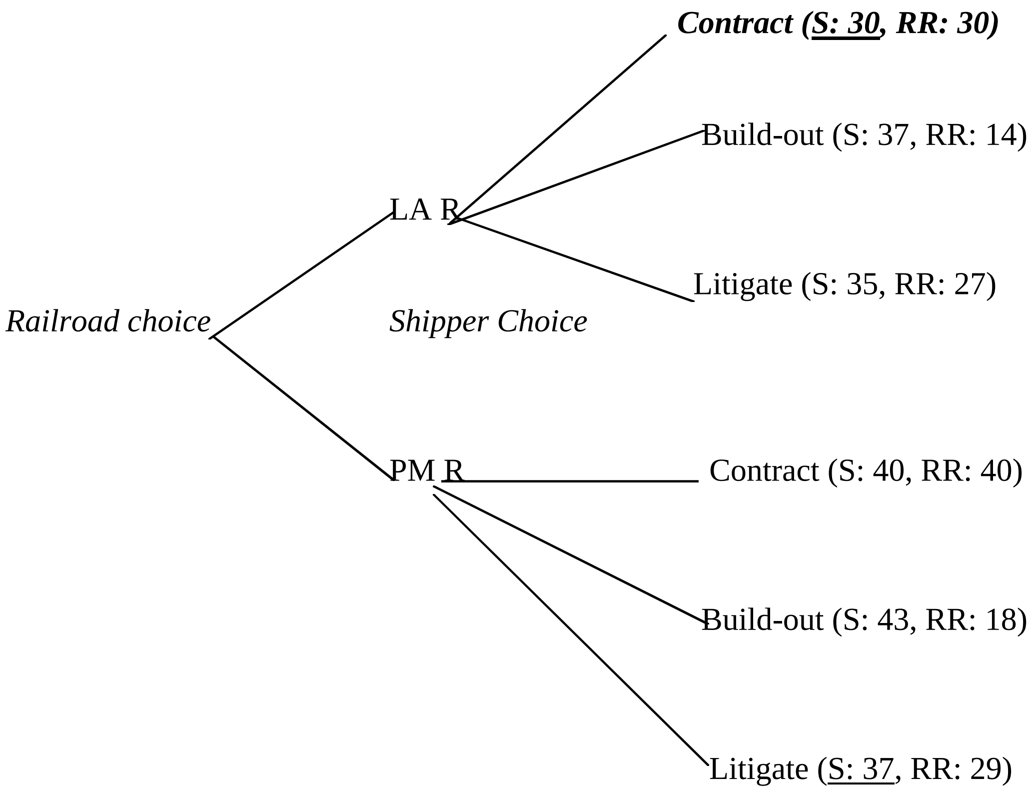
When the railroad considers its first move, it will also consider what will be the shipper's likely reaction. The shipper's payoffs are costs, which it will want to minimize. The railroad will consider as a result of its choice which branch has the lowest cost for the shipper and will choose accordingly.

Here are the base case assumptions:

Build-out cost	**$25 million**
Build-out period	**2 years**
Contract term	**5 years**
Shipment size	**1 million tons**
PM rate (calculated)	**$19.53/ton**
Shipper litigation expense	**$ 4 million**
Railroad litigation expense	**$ 4 million**

Now we review the decision tree populated with the results (the decision tree is on next page). 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 3 outcomes. This outcome means $30 milllion in economic profit 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 economic profit to the railroad. The railroad chooses to set an LAR rate and the outcome is a contract. See the following decision tree.

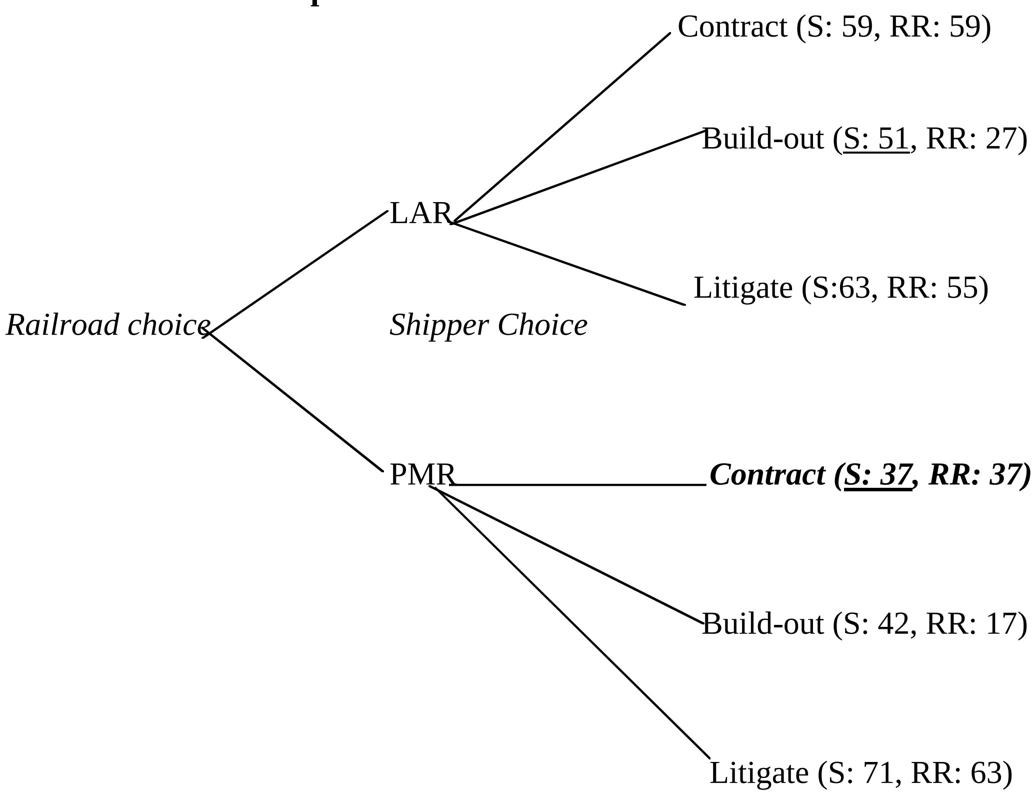
Base Case
Decision tree:



IV. Extensions

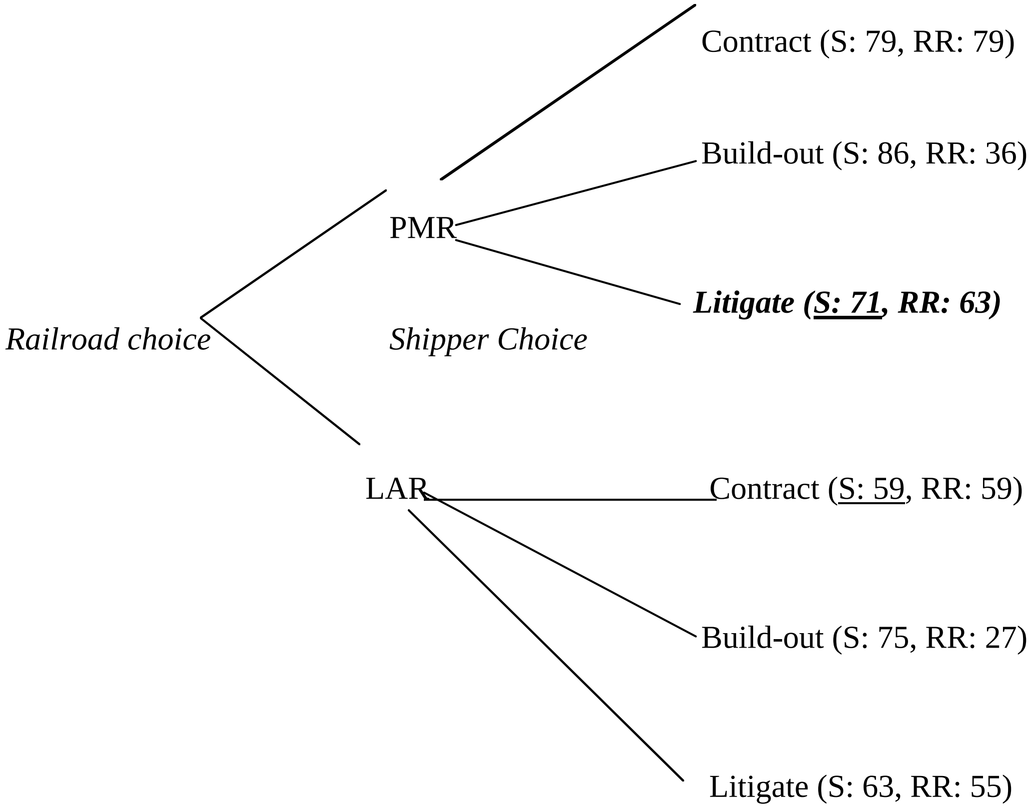
To calibrate the model, we alter a few of the base case assumptions. This also allows some analysis of how changing various parameters might affect railroad and shipper decisions to contract, litigate or build-out. The first assumption to adjust is shipment size, which we will double, while keeping all other base case values unchanged.

Decision tree when shipment size doubles:



Double the shipment size - When we double the shipment size, there are obviously more tons. Because there are more tons, the PMR falls to $14.51/ton. This rate is below the assumed regulatory ceiling of 180% or $18.00/ton so litigation would in fact fail. If the railroad tried to charge above $15.51 (where the shipper is indifferent to a build-out), the shipper would buildout. The LAR is above $15.51 so the shipper would choose to build out, which leaves railroad profits at $27 million. Seeing that result, the railroad offers PMR and the parties contract.

Decision tree when build-out is doubled to $50 million:



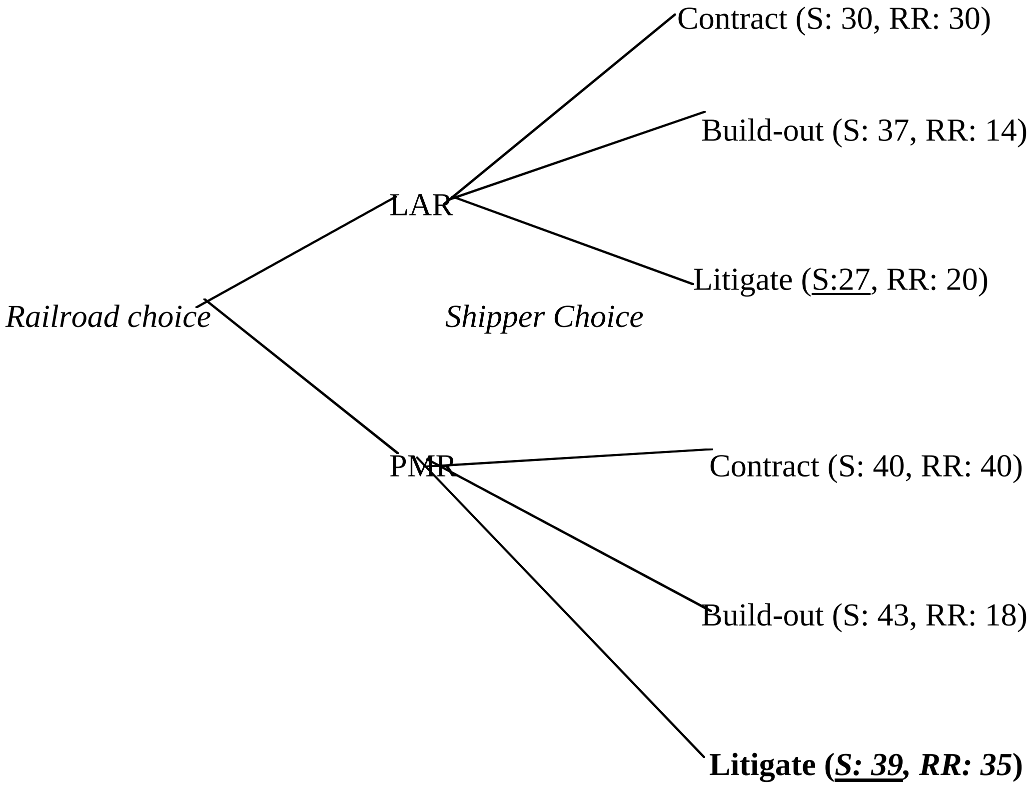
Double build-out cost from $25 million to $50 million – Increasing the cost of the build-out is equivalent to making the shipper more dependent on the railroad, i.e., "more captive." We continue to assume that the shipment size is 2 million tons. The railroad chooses to litigate because the difference between 180% rate that would be set by the Board during litigation and the LA rate compensates the railroad for litigation expenses.

Regulatory Agency Perceived As Arbitrary

If the agency is perceived as arbitrary, it means that parties perceive that the agency may find a "reasonable" rate, "unreasonable" and vice versa. For example, the parties might perceive that the agency may incorrectly set a rate below the statutory threshold. This is captured by a new term: IRM. IRM represents a rate ceiling of 136% of URCS variable costs instead of 180%. On the other hand, the railroad would perceive possible gains if it thought it could achieve rates 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. In previous examples this "*p*" is equal to one. The new equations are:

event	***equation***
Shipper cost if LAR & litigate	$F+\left(p*\left(\sum_0^n\left[\frac{LAR-MC}{(1+i)^n}\right]*S\right)\right)+\left(\{1-p\}*\left(\sum_0^n\left[\frac{IRM*MC}{(1+i)^n}\right]*S\right)\right)$
Shipper cost if PMR & litigate	$F+\left(p*\left(\sum_0^n\left[\frac{RM*MC}{(1+i)^n}\right]*S\right)\right)+\left(\{1-p\}*\left(\sum_0^n\left[\frac{PMR-MC}{(1+i)^n}\right]*S\right)\right)$
Railroad profit if LAR & litigate	$-H+p*\left(\sum_0^n\left[\frac{LAR-MC}{(1+i)^n}\right]*S\right)+\{1-p\}*\left(\sum_0^n\left[\frac{IRM*MC}{(1+i)^n}\right]*S\right)$
Railroad profit if PMR & litigate	$-H+p*\left(\sum_0^n\left[\frac{RM*MC}{(1+i)^n}\right]*S\right)+\{1-p\}*\left(\sum_0^n\left[\frac{PMR-MC}{(1+i)^n}\right]*S\right)$

Decision Tree When Regulatory Agency Perceived As Arbitrary



Reviewing the railroad's analysis of shipper reactions and a perceived arbitrary regulatory agency 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.

V. Discussion

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 then 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 exercising 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 competitive 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 "roll the dice" on litigation rather than contract because they perceive an arbitrary agency may provide windfalls.

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