Is It Necessary To Regulate Prices In Freight Transport Markets?

By William Hurley*

1. Introduction

In this era of deregulated freight transport markets, shippers and carriers are free to contract in any way they see fit. Perhaps the only limitation on freight rates occurs when a shipper is deemed to be captive. Most countries have implemented legislation which protects captive shippers. For instance, in the US, a captive shipper can appeal against rates that exceed 180 per cent of carrier variable cost. For a discussion of these and related issues, see Braeutigam (1993) and Roberts (1983).

The efficiency argument for captive shipper protection proceeds in this way. A carrier who has a shipper captive will behave like a monopolist and charge rates that exceed marginal cost. The shipper will not move as high a quantity to market as he otherwise would. Therefore efficiency could be enhanced by forcing the carrier to lower his rates.

In this paper we argue that this logic is incorrect. In fact, we argue that *forcing a carrier to price a captive shipper at marginal cost will not enhance efficiency.*

We study a single shipper who is a monopolist in a spatially-separated delivered market, as shown in Figure 1. The shipper's manufacturing plant is located at node *S*. He wishes to move his output to a delivered market at node *D*. His means of reaching node *D* is the transport system.

To make our point, we study a variety of regulatory regimes for the transport system. In the *Monopoly* structure, a single carrier controls the transport infrastructure between nodes *S* and *D*. This is shown in Panel A of Figure 2 where a single arc connects *S* and *D*. This carrier is free to charge whatever tariff he chooses. We contrast this regime of commercial freedom with a *Regulated Monopoly* structure where the carrier is forced to charge a unit price for transport equal to marginal cost.

A second set of regulatory regimes posits a transport system having two carriers, shown in Panel B of Figure 2. In the *Duopoly* structure, both carriers are free to charge any tariff they choose. This is contrasted with the *Regulated Duopoly* structure, where both transport firms are forced to price at marginal cost.

In each of these situations we focus on what *output* the shipper chooses. Our key results are these:

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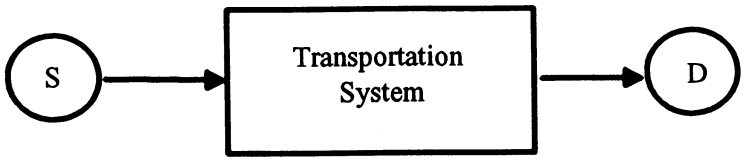

Figure 1
The Spatial Configuration of the Shipper and Delivered Market

Panel A
The MONOPOLIST Market Structure

Panel B
The DUOPOLIST Market Structure

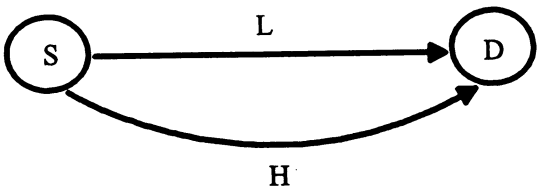

Figure 2

1. The shipper chooses the same output in the *Monopoly* and *Regulated Monopoly* structures; and
2. The shipper chooses the same output in the *Duopoly* and *Regulated Duopoly* structures.

Thus, since neither the *Regulated Monopoly* nor *Regulated Duopoly* results in the shipper choosing a higher output, marginal cost pricing does not enhance efficiency.

The intuition for these results turns on two very powerful carrier incentives. First, a carrier would like to discriminate whenever possible. This is a general motivation for most sellers. If a seller can differentiate buyers, he can usually make his profits larger by extracting a higher share of a market's consumer surplus. In the rail industry, carriers discriminate by contracting with individual shippers. In fact, most, if not all, tariffs on unit train bulk commodity movements in North America are written on specific origins and destinations.

The second incentive is less well understood in the context of freight transport markets. Suppose the shipper and carrier are modelled as a vertical economy: the carrier (upstream firm) offers a tariff (price) to the shipper (downstream firm), and given this tariff, the shipper chooses an output to send to market. It is well known that the carrier can offer a non-uniform price which forces the shipper to choose the output that maximises joint carrier-shipper profit. (The interested reader is referred to Tirole (1988) for a summary of the vertical exchange literature.) A characteristic of this non-uniform price is that the shipper would not choose a different output from the one he would choose if the carrier were forced to price at marginal cost. Thus, forcing the carrier to price at marginal cost would not enhance efficiency.

This approach to examining the effects of regulation differs from the existing literature in an important way. The usual approach begins with a downward sloping demand for freight transport. That is, individual shippers are aggregated and their behaviour is summarised by a single downward-sloping demand curve. Such an analysis must necessarily result in a single uniform price for transport which all shippers pay. An example of this approach is the paper by Braeutigam (1979). In contrast, our analysis breaks apart the demand curve and focuses on the interaction between individual shippers and carriers on specific OD demands. In this way we are able to incorporate the rich literature of vertical control.

2. The *Monopoly* and *Regulated Monopoly* Market Structures

The shipper's delivered market at node D is willing to pay $p_0(x)$ for x delivered units. Thus, the shipper's revenue is $xp_0(x)$. For convenience, $p_0(x)$ is assumed to be strictly monotonically decreasing.

The shipper's costs consist of a manufacturing cost, $C_0(x)$ and a shipping cost, $R(x)$. $C_0(x)$ consists of all the shipper's costs to put the product at the plant door at node S. The shipping cost, $R(x)$, is what the shipper has to pay the carrier to move the product along arc C to the delivered market.

Given our assumptions, the shipper's profit is given by

$$\pi_0(x\,|R) = xp_0(x) - C_0(x) - R(x). \tag{1}$$

The shipper's problem (or *follower* problem) is

$$\max_x \pi_0(x\,|R) \qquad (F)$$

$$\text{s.t. } \pi_0(x\,|R) \geq 0,\ x \geq 0.$$

That is, the shipper must choose some non-negative output given the carrier's price, and

at this price, shipper profit must be non-negative. Suppose that, given a carrier tariff R, $\hat{x}(R)$ solves this problem.

The carrier's cost of moving x units to the shipper's delivered market is $C(x)$ where we assume $C(0) = 0$. Typically, a carrier will service many shippers over his infrastructure. Thus, to be more precise, $C(x)$ represents the carrier's *incremental cost* of serving the shipper. That is $C(x)$ is the amount a carrier's total cost goes up when x rather than 0 units of the shipper's output are moved.

The carrier's profit function is given by

$$\pi(R \mid x) = R(x) - C(x). \tag{2}$$

The carrier's problem (the *leader* problem) is to

$$\max_{R(x)} \pi[R \mid \hat{x}(R)]. \tag{L}$$

We assume that $[x^B, R^B(x)]$ is an equilibrium for this problem.

Before characterising the solution of the bilevel problem we examine two notions of efficiency.

Vertical efficiency

Suppose a single agent owns the carrier and shipper. This agent's profit function, termed the *vertically integrated profit function*, is

$$\Gamma(x) = xp_0(x) - C_0(x) - C(x). \tag{3}$$

$\Gamma(x)$ is assumed to be strictly concave with a maximum at x^*. We term x^* the *vertically efficient output.* Assuming an interior optimum, x^* solves

$$\Gamma'(x^*) = x^*p'_0(x^*) + p_0(x^*) - C'_0(x^*) - C'(x^*) = 0. \tag{4}$$

This is particularly important in the context of the shipper/carrier problem, in that the largest profit that the shipper and carrier can generate requires the shipper to choose the output x^*. Any other output lowers their combined profit.

Economic efficiency

Economic efficiency is different from vertical efficiency. Vertical efficiency does not take into account the welfare of consumers in the shipper's delivered market. Therefore, to take account of consumers in the delivered market, we examine the standard welfare function for the shipper/carrier problem we have posed:

$$W(x) = \int_0^x p_0(x)dx - C_0(x) - C(x) \ . \tag{5}$$

We assume that $W(x)$ is maximised at output $x^W > 0$. Therefore x^W solves

$$p_0(x) - C'_0(x) - C'(x) = 0. \tag{6}$$

In general, we can show that $x^W > x^*$ if $\Gamma(x)$ is strictly concave. But the important thing to note is that, in comparing various regulatory regimes, the one which has the highest allocative economic efficiency is the one which produces the highest output, x.

Now we turn to the solution of the bilevel problem.

Proposition 1:
The solution of the shipper/carrier problem is:

$$x^B = x^* \tag{7a}$$

and

$$R^B(x) = \begin{cases} \Gamma(x^*) + C(x) & x > 0 \\ 0 & x = 0 \end{cases} \tag{7b}$$

Proof:
First examine the shipper's incentive. Assuming the shipper chooses a positive output, this will satisfy the first derivative of the shipper's profit function:

$$\pi_0'(x) = xp'_0(x) + p_0(x) - C'_0(x) - C'(x) = 0. \tag{8}$$

By definition x^* solves this condition. Therefore, if the shipper chooses a positive output, it will be x^*.

At x^* the shipper's profit is

$$\pi_0(x^* \,|R^B) = x^* p_0(x^*) - C_0(x^*) - C(x^*) - \Gamma(x^*) = 0. \tag{9}$$

We assume that zero profit is defined in such a way that the shipper chooses to move a positive output rather than zero output. Thus, given $R^B(x)$ the shipper will choose x^*.

Now consider the carrier. Since the shipper chooses the vertically-efficient output, and the carrier is extracting all of this vertically efficient profit (the carrier is setting $b = \Gamma(x^*)$ there can be no other tariff which produces a higher profit for the carrier. Therefore $R^B(x)$ is an optimal tariff for the carrier. And the proof is complete.

Before proceeding we can make several comments. First, as shown in Hurley (1994), for a single downstream firm and any number of upstream firms with *generalised* upstream cost functions, $C_i(x)$ an optimal form of tariff is cost-plus. That is, each upstream firm can choose a tariff having the form $b_i + C_i(x)$. In the case of two upstream firms and strictly convex upstream costs, two-part tariffs are not equilibrium tariffs (as we shall see in the next section). For this reason we have used the cost-plus form of non-uniform tariff rather than two-part tariffs. Of course, in the case of one shipper and one carrier, a two-part tariff, $b + mx$, can be an equilibrium tariff.

A second comment relates to the harshness of the solution. The carrier is able to extract all of the vertically efficient profit. This is because the shipper does not have a transport alternative. In the next section, we study the case of two carriers. In this case, the shipper will be able to extract some of the vertically integrated surplus. The amount he can extract will depend on the "closeness" of carrier costs. In the case where the carriers have equal costs, the shipper will be able to extract all of the vertically efficient surplus.

We now relate the outcome of the *Regulated Monopoly* structure to this *Monopoly* outcome. Suppose the carrier is forced to charge a unit price for transport equal to marginal cost at the vertically efficient output, $C'(x^*)$. What does the carrier produce now?

Proposition 2:
Suppose a regulator forces the carrier to charge a unit price equal to marginal cost, that is, $R^M(x) = C'(x^*)x$. Then the shipper will choose an output x^*.

Proof:
At $R^M(x)$, the shipper's profit is:

$$\pi_0(x\,|R^M) = xp_0(x) - C_0(x) - C'(x^*)x\,. \tag{10}$$

Assuming an interior solution, the first-order condition is

$$\pi_0'(x) = xp'_0(x) + p_0(x) - C'_0(x) - C'(x^*) = 0, \tag{11}$$

and x^* solves this condition. Therefore the shipper chooses x^* and the proof is complete.

The import of this proposition is that, under the *Monopolist* and *Regulated Monopolist* structures, the shipper has no incentive to change output. In each case he chooses x^*. Thus, *relative to commercial freedom, regulating the carrier to price at marginal cost will not enhance economic efficiency.*

This result may have some implications for the issue of privatisation. For instance, suppose a government-controlled transport firm charged *uniform* prices in its various OD markets and that these prices exceeded marginal cost (possibly Ramsey prices). This situation is, we believe, a fair characterisation of some North American OD markets before the deregulation of the 1980s. Then, presumably, privatisation would put the tariff decision in the hands of those interested in profit. These profit-takers would then offer non-uniform prices which would cause shippers to choose the same output they would have chosen had the government priced at marginal cost. Given these non-uniform prices, shippers would choose to move more output, and economic efficiency would be enhanced. Thus, to the extent that a government-controlled transport firm used Ramsey prices, privatisation would lead to a welfare gain. This appears to be consistent with the evidence in North America: since deregulationfreight traffic volume has increased substantially, and much more so than the expanding North American economy of the 1980s would account for.

3. The *Duopoly* and *Regulated Duopoly* Market Structures

Now consider two carriers competing to move a single shipper's freight to a delivered market. We do not restrict the carriers to the same costs. To this end, we assume that the cost function (incremental cost function) of the lower cost carrier, termed the *LC-carrier*, is given by $C_L(x_L)$ where x_L is the output the shipper moves with the LC-carrier. The cost function of the higher cost carrier, termed the *HC-carrier*, is given by $C_H(x_H)$ where x_H is the output moved with the HC-carrier.

Referring to Panel B of Figure 2, consumers at D are prepared to pay the shipper a price $p_0(x_L + x_H)$ if he moves output $x_L + x_H$ to this market. The shipper has two costs. $C_0(x_L + x_H)$ is the shipper's cost of manufacturing, and represents all costs to get the product to the plant door. The other cost is what the shipper must pay the carriers to move his product to consumers at D. Let $R_L(x_L)$ be the tariff the LC-carrier charges the shipper to move x_L units of output to the delivered market. In a similar fashion, we define $R_H(x_H)$.

Given these assumptions, the shipper's profit is given by

$$\pi_0(x_L x_H\,|R_L R_H) = (x_L + x_H)p_0(x_L + x_H) - C_0(x_L + x_H) - R_L(x_L) - R_H(x_H). \tag{12}$$

The LC-carrier's profit is

$$\pi_L(R_L \,|x_L,x_H) = R_L(x_L) - C_L(x_L), \tag{13a}$$

and the HC-carrier's profit is

$$\pi_H(R_H \,|x_L,x_H) = R_H(x_H) - C_H(x_H). \tag{13b}$$

The bilevel structure of the game is as follows. The two carriers form the upper level, each selecting a tariff. The shipper forms the lower level, and given the carrier tariffs, selects an output to move over each carrier. Suppose $(\hat{x}_L,\hat{x}_H)$ solves the shipper's problem

At the higher level, the LC-shipper solves

$$\max_{R_L} \pi(R_L \,|\hat{x}_L,\hat{x}_H) \tag{14a}$$

and the HC-carrier solves

$$\max_{R_H} \pi(R_H \,|\hat{x}_L,\hat{x}_H) \tag{14b}$$

and these problems are solved simultaneously. Suppose this bilevel game is solved by $(x_L^B, x_H^B, R_L^B, R_H^B)$.

Let $\Gamma(x_L,x_H)$ be the vertically-integrated profit function of all three players:

$$\Gamma(x_L,x_H) = (x_L + x_H)p_0(x_L + x_H) - C_0(x_L + x_H) - C_H(x_H) - C_L(x_L). \tag{15}$$

We assume that Γ is maximised at $(x_L^*,x_H^*) \geq 0$, where $\Gamma^* = \Gamma(x_L^*,x_H^*)$.

The vertically-integrated profit of the LC-carrier and shipper, *assuming the HC-carrier moves zero output*, is $\Gamma(x_L,0)$. We assume that $\Gamma(x_L,0)$ is maximised by $\bar{x}_L^* > 0$ where $\Gamma_L^* = \Gamma(\bar{x}_L^*,0)$ In a similar way we define the vertically integrated profit of the HC-carrier, assuming the LC-carrier moves zero output. We assume that $\Gamma(0,x_H)$ is maximised at $\bar{x}_H^* > 0$ where $\Gamma_H^* = \Gamma(0,\bar{x}_H^*)$.

The following proposition identifies the solution for this 1-shipper/2-carrier problem.

Proposition 3

The solution of the 1-shipper/2-carrier problem is

$$(x_L^B,x_H^B) = (x_L^*,x_H^*) \tag{16a}$$

$$R_L^B(x) = \begin{cases} \Gamma^* - \Gamma_H^* + C_L(x) & x > 0 \\ 0 & x = 0 \end{cases} \tag{16b}$$

and

$$R_H^B(x) = \begin{cases} \Gamma^* - \Gamma_L^* + C_H(x) & x > 0 \\ 0 & x = 0 \end{cases} \tag{16c}$$

Proof:

Suppose that an optimal form of carrier tariff is $R_i(x) = b_i + C_i(x)$ for $i = L,H$. Given these tariffs, the shipper has three alternatives: he can use both carrier tariffs, or only the LC-carrier's tariff, or only the HC-carrier's tariff.

Suppose the shipper chooses to use both tariffs. Then we can write the shipper's profit function as

$$\pi_0(x_L,x_H) = \Gamma(x_L,x_H) - b_L - b_H, \tag{17}$$

and if b_L and b_H are sufficiently small, it is clear that he will choose (x_L^*, x_H^*) since, by definition, this point maximises Γ. At this output profits are:

$$\pi_0(x_L^*, x_H^*) = \Gamma^* - b_L - b_H, \tag{18a}$$

$$\pi_L(x_L^*) = b_L, \tag{18b}$$

$$\pi_H(x_H^*) = b_H. \tag{18c}$$

Now, suppose it is optimal for the shipper to choose only the LC-carrier. Then shipper profit is

$$\pi_0(x_L, x_H) = \Gamma(x_L, 0) - b_L, \tag{19}$$

so the shipper chooses $\bar{x}_L^*$, and profits are

$$\pi_0(x_L^*, 0) = \Gamma_L^* - b_L \tag{20a}$$

$$\pi_L(x_L^*) = b_L. \tag{20b}$$

The final possibility is that the shipper chooses to use only the HC-carrier. In this case, output is $\bar{x}_H^*$ and profits are

$$\pi_0(0, \bar{x}_H^*) = \Gamma_H^* - b_H \tag{21a}$$

$$\pi_H(x_H^*) = b_H. \tag{21b}$$

We now examine the conditions under which the shipper will choose to use both carriers. This will happen if

$$\pi_0(x_L^*, x_H^*) > \pi_0(\bar{x}_L^*, 0) \text{ and } \pi_0(x_L^*, x_H^*) > \pi_0(0, \bar{x}_H^*) \tag{22}$$

or if

$$b_H < \Gamma^* - \Gamma_L^*, \tag{23a}$$

$$b_L < \Gamma^* - \Gamma_H^*. \tag{23b}$$

(There is an indifference point when one or both these conditions hold with equality.)

The shipper will choose only the LC-carrier if

$$b_H > \Gamma^* - \Gamma_L^*, \tag{24a}$$

$$b_L - b_H < \Gamma_L^* - \Gamma_H^*. \tag{24b}$$

Finally, the shipper will choose only the HC-carrier if

$$b_L > \Gamma^* - \Gamma_H^*, \tag{25a}$$

$$b_L - b_H > \Gamma_L^* - \Gamma_H^*. \tag{25b}$$

We now claim that, given this form of carrier tariff, the carriers will choose

$$b_L = b_L^B = \Gamma^* - \Gamma_H^*, \tag{26a}$$

$$b_H = b_H^B = \Gamma^* - \Gamma_L^*. \tag{26b}$$

To see this, suppose the LC-carrier chooses b_L^B and the HC-carrier chooses $b_H < b_H^B$. Then the HC-carrier can increase profit by raising b_H to b_H^B since the shipper will continue to choose both carriers. A similar argument shows that the LC-carrier will never choose $b_L < b_L^B$.

Now, suppose the HC-carrier chooses an output $b_H > b_H^B$. Then the LC-carrier can choose $b_L = b_H + \Gamma_H^* - \Gamma_L^* - \varepsilon$, where $\varepsilon > 0$, and at b_L, the shipper will choose to move zero output over the HC-carrier. Thus HC-carrier profit will go to zero. Thus the HC-

carrier will not choose $b_H > b_H^B$. A similar argument can be made for the LC-carrier.

Now we argue the optimality of the assumed form of carrier price. The question is whether the LC-carrier can find another form of price scheme which increases profit, holding the form of the HC-carrier's fixed at $b_H + C_H(x)$. Suppose there is a scheme and that this scheme gives the LC-carrier profit of

$$\pi_L > \Gamma^* - \Gamma_H^*. \tag{27}$$

Whatever this price scheme, the shipper must make profits at least those he would make if he used only the HC-carrier, or

$$\pi_0 \geq \Gamma_L^* + \Gamma_H^* - \Gamma^*. \tag{28}$$

The implication of (27) and (28) is that

$$\pi_0 + \pi_L > \Gamma_L^*, \tag{29}$$

which is impossible since $\pi_0 + \pi_L$ can be no greater than Γ_L^* by definition.

Thus there is no price scheme which will make the LC-carrier's profit higher, and $b_L^B + C_L(x)$ is an optimal form for the LC-carrier's price. Along similar lines, we argue the optimality of the HC-carrier's price. And the proof is complete.

Thus, in a regime of commercial freedom, carriers offer non-uniform prices which cause the shipper to choose outputs x_L^* and x_H^*, which maximise the joint profit of all three agents (shipper and both carriers).

Before proceeding with a statement of the main result, we make two comments on the equilibrium specified in Proposition 3. First, note that there is no requirement that the shipper move positive output over both carriers. In fact, for the case where both carriers have constant marginal cost, the optimal tariffs will be two-part tariffs, and in the case where the LC-carrier has a lower constant marginal cost, the shipper will move all of his output over the LC-carrier. A second point relates to profit distribution. Note that the carriers are not able to extract all of the vertically integrated maximal profit. Moreover, as $C_H(x)$ approaches $C_L(x)$ the profits of both carriers approach zero and those of the shipper approach the maximum vertically integrated profit. Thus the rent that a shipper is able to extract depends critically on how good his second best alternative is.

Proposition 4:
Suppose a regulatory authority forces the LC and HC carriers to charge a unit price of $C_L'(x_L^*)$ and $C_H'(x_H^*)$ respectively. Then the shipper will choose outputs x_L^* and x_H^*.

Proof:
The proof is straightforward. As in Proposition 2, it is a matter of showing that the shipper's first-order conditions are solved by x_L^* and x_H^*.

Again, the imposition of marginal cost pricing will not enhance economic efficiency since, in the case of marginal cost regulation (*Regulated Duopoly*), the shipper will move exactly the same outputs as he would under a regime of commercial freedom (*Duopoly*).

Thus a regime of marginal cost pricing of transport service, relative to commercial freedom, will not enhance economic efficiency.

4. Conclusions

In this paper we have argued that marginal cost price regulation in freight transport markets cannot enhance efficiency. The rationale is that, relative to a regime of commercial freedom, a shipper would not change the output that he moved to market if marginal cost pricing were imposed. The key to this result is that a carrier's optimal non-uniform price has the characteristic that a shipper will choose the same output he would have chosen had the carrier priced at marginal cost. It would appear that the economic rationale for regulating freight rates must appeal to fairness.

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Date of receipt of final manuscript: April 1994