Service Quality and Industry Structure

Concentration in the LTL Motor Carrier Industry

By Dong Liu*

1. Introduction

The Motor Carrier Act of 1980 largely deregulated the US interstate motor carrier industry. By lifting restrictions on entry and rates, deregulation has greatly enhanced the efficiency of carrier operations and brought substantial benefits to shippers (see Winston, Corsi, Grimm and Evans, 1990).

Deregulation has also led to some significant changes in the industry structure. This is particularly the case in the less-than-truckload (LTL) sector, the largest class of general freight carriers. Since deregulation, intense competition has driven many LTL carriers out of business and the industry has become increasingly concentrated (Rakowski, 1988; Keeler, 1989; Kling, 1990; Emerson, Grimm and Corsi, 1992). As documented by Emerson, Grimm, and Corsi (1992), the total number of LTL carriers has declined from 552 in 1977 to 274 in 1988, and the revenue share of those large LTL carriers (with revenues more than 1 per cent of the total) has grown from 37.6 per cent of the industry total in 1977 to 68.5 per cent in 1988.

It is puzzling that both early and more recent empirical cost studies have found no evidence of scale economies in the motor carrier industry. There have been more than a dozen such studies between 1977 and 1991. With few exceptions, they have consistently concluded that the motor carrier industry as a whole, and the LTL sector in particular, have a constant returns-to-scale cost structure. The study by Grimm, Corsi and Jarrell (1989) contains a review of many of them. The results of these studies, together with the fact that the trucking technology and inputs are easily accessible, seem to indicate that the LTL motor carrier industry is inherently competitive; once the regulatory controls on rates and entry were removed, the industry structure would approximate to that of perfect competition and a large number of competing carriers would survive. This certainly has not been the case.

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A major problem with these studies is that none of them had controlled carriers' service quality attributes such as transit time, reliability, and so on (for example, Daughety, 1985; Keeler, 1989). Cost estimation without controlling service quality implicitly assumes identical service quality among all the carriers. Yet carriers' service quality levels vary widely in the market (see *Distribution*, 1983-1992), and it has long been recognised that service quality is among shippers' major concerns when choosing a carrier (for example, McGinnis, 1990).

This paper establishes a link between the carriers' quality differentiated services and the industry's high concentration from the perspective of the differentiated product theory. It develops an equilibrium model where carriers take their service quality levels as given and compete by setting their rates. Under the condition that the cost increases of high service quality carriers are not beyond what shippers are willing to pay for the high quality services, it is shown that only a very small number of competing carriers can coexist in a market. An upper bound on the number of competing carriers is derived and empirically measured.

The basic model framework was first studied by Gabszewicz, Shaked, Sutton and Thisse (1981), and then extended by Shaked and Sutton (1983). The duopoly case of the model has been used to analyse the deregulation of local bus services in Great Britain (Dodgson and Katsoulacos, 1988), and the competitive access agreements issues of US railroads (Liu, 1992).

2. A Rate Competition Model

Consider n carriers providing transport services from an origin city to a destination city. Carrier k, k=1, 2,...,n, charges a rate of p_k per unit weight for a transit time of t_k. Transit time is used here as a proxy for the carrier's overall service quality.

As a result of greater rate flexibility since deregulation, carriers can change their rates much more quickly and with far less cost than they can their service quality levels. This is especially the case with LTL carriers. Typical LTL operation includes local pick-ups and deliveries, line-hauls, terminal consolidation and dispersion of loads, and potential break-bulk handlings. Improving service quality involves rescheduling and coordinating every aspect of the operation. Moreover, it would probably involve opening up new routes and new terminals, and relocating old terminals. As a result, improving LTL service is a time-consuming and fixed and sunk cost process. To capture this characteristic, it is assumed that the carriers consider their service quality as given and choose their respective rates to maximise their profits. This is thus a final stage game. It should be noted that since the costs of setting up service quality are sunk in the rate competition stage, the model assumes non-contestability.

As pointed out in the introduction, the existing cost studies did not fully incorporate carriers' service quality characteristics in their output specifications (Daughety, 1985; Keeler, 1989). This implicitly assumed identical service quality levels among all the carriers. Yet carriers' service quality levels are far from homogeneous and shippers examine them very carefully when choosing carriers (see *Distribution*, 1983-1992;

McGinnis, 1990). To examine the implication of non-homogeneous service quality, the case where carriers offer distinctive service qualities is considered. Without loss of generality, assume that carriers 1 to n offer increasingly higher quality services, that is, $t_1 > t_2 > \ldots > t_n$, since lower transit time represents higher service quality. The case of identical service quality will be discussed later.

Note that the service quality differentiation here is of the "vertical" kind, meaning that service quality is captured by a one-dimensional index and that shippers always prefer high service quality to low service quality (when the rates are not taken into account). This is to reflect the fact that since deregulation, motor carriers have been competing by tailoring their services to meet each individual shipper's needs, rather than just offering one type of service for different shipping requirements (Johnson and Schneider, 1991). This single index formulation is also supported by the theoretical finding of Allen and Liu (1993) that shippers would not favour those carriers who emphasise only one aspect of their services but ignore the others.

Shippers in the origin city are assumed to have differently valued shipments. Denote y as a shipper's shipment value, where y is measured by the dollar value per unit weight. Denote the range of y as $[a, b]$, where a and b correspond to the minimum and maximum shipment values. Then, for transport rate p_k and transit time t_k, the unit shipping cost to shipper y is $p_k + yq(t_k)$, where a general function $q(t_k)$ is used to represent service quality related costs (for example, shipment-in-transit inventory cost, out-of-stock cost, and so on) per unit shipment value. $q(t_k)$ is an increasing function of t_k since high transit time t_k means low service quality and low service quality leads to high shipper cost $q(t_k)$. Assume that shippers choose a carrier which gives them the lowest unit shipping cost. Denote y_k as the shipment value such that the unit costs of sending it by carrier k or carrier $k-1$ are the same:

$$p_k + y_k q(t_k) = p_{k-1} + y_k q(t_{k-1}),$$

from which y_k is obtained:

$$y_k = \frac{p_k - p_{k-1}}{q(t_{k-1}) - q(t_k)}, \quad k = 2,3,\ldots, n, \tag{1}$$

It is easy to see that shippers with $y > y_k$ prefer carrier k to carrier $k-1$, and shippers with $y < y_k$ prefer carrier $k-1$ to carrier k. Since $t_{k-1} > t_k$, p_k must be greater than p_{k-1}, in order for y_k to be in $[a, b]$. This reflects the fact that shippers with high-valued shipments prefer paying more for high quality services than shippers with low-valued shipments. The practice that carriers charge more for high-valued shipments is called value-of-pricing. For evidence of value-of-pricing in competitive trucking markets, see Beilock (1985) and McMullen (1985).

Then, $y_2, y_3, \ldots, y_n$ divide the shipper group into n segments according to their choice of carriers. This is illustrated in Table 1.

Define $w(y)$ as a freight density function such that the total weight of those shipments ranging from a to y is given by

$$\int_a^y w(y)dy.$$

Table 1

Shippers' Choice of Carriers

Shipment Values	$[a, y_2]$	$[y_2, y_3]$	...	$[y_k\ y_{k+1}]$	...	$[y_n, b]$
Carriers	1	2	...	k	...	n

Then, the amount of freight that carrier 1 carries is given by

$$\int_a^{y_2} w(y)dy,$$

for carrier k, it is

$$\int_{y_k}^{y_{k+1}} w(y)dy, \text{ where } k = 2, 3,\ldots, n-1,$$

and for carrier n, it is

$$\int_{y_n}^{b} w(y)dy.$$

Assume that a carrier's total costs are in the form of $c(t)z$, where z is the total amount of freight the carrier carries, t is the transit time, and $c(t)$ is the marginal cost. $c(t)$ is a decreasing function of t since lowering transit time t would in general increase marginal cost $c(t)$. Note that when transit time t is ignored or assumed to be constant among all the carriers, the carrier's cost formulation $c(t)z$ corresponds to a constant returns-to-scale cost structure; and by the conventional perfect competition theory, an infinite number of carriers can compete and stay in a market. However, when t is differentiated among all the carriers, it will be shown that only a small number of competing carriers may coexist in a market.

The profit function of each carrier is given by:

$$\begin{aligned}
\pi_1 &= [p_1 - c(t_1)] \int_a^{y_2} w(y)dy, && k = 1, \\
\pi_k &= [p_k - c(t_k)] \int_{y_k}^{y_{k+1}} w(y)dy, && k = 2, 3,\ldots, n-1, \qquad (2) \\
\pi_n &= [p_n - c(t_n)] \int_{y_n}^{b} w(y)dy, && k = n.
\end{aligned}$$

The Nash equilibrium is used as the solution concept, that is, each carrier sets its rate to maximise its profit, taking other carriers' rates as given. The first-order condition of profit maximisation is as follows:

$$\pi_1' = \int_a^{y_2} w(y)dy - \frac{[p_1 - c(t_1)]w(y_2)}{q(t_1) - q(t_2)} = 0, \qquad k = 1,$$

$$\pi_k' = \int_{y_k}^{y_{k+1}} w(y)dy - [p_k - c(t_k)]\left[\frac{w(y_{k+1})}{q(t_k) - q(t_{k+1})} + \frac{w(y_k)}{q(t_{k-1}) - q(t_k)}\right] = 0 \qquad k = 2,3,\ldots,n-1, \quad (3)$$

$$\pi_n' = \int_{y_n}^{b} w(y)dy - \frac{[p_n - c(t_n)]w(y_n)}{q(t_{n-1}) - q(t_n)} = 0, \qquad k = n.$$

Gabszewicz, Shaked, Sutton and Thisse (1981) have studied this kind of model and derived conditions to ensure the existence of a Nash equilibrium. For the model here, a Nash equilibrium exists if $w(y)$ satisfies the following:

$$[w(y)]^2 + w'(y)\int_y^b w(s)ds > 0$$
$$[w(y)]^2 - w'(y)\int_a^y w(s)ds > 0 \qquad (4)$$

It is proved that condition (4) ensures the existence of equilibrium and is satisfied by general concave functions and a variety of (truncated) distributions including Uniform, Normal, Rayleigh, Exponential and Gamma.[1]

3. Number of Carriers

This section first presents a condition on the carrier's marginal cost $c(t)$ and the shipper's service quality related unit cost $q(t)$. It then shows how this condition leads to a constraint on the number of competing carriers in a market.

The condition on $c(t)$ and $q(t)$ can be stated as follows: the marginal cost increases to a carrier which improves its service quality are less than the corresponding service related cost savings to shipper a, the shipper with the lowest valued shipment (and to all the other shippers as well since $y > a$). In other words, service quality improvement brings net cost savings to carriers and shippers as a whole. This condition can be written as:

$$c(t_k) - c(t_{k-1}) \le aq(t_{k-1}) - aq(t_k), \qquad k = 2,3,\ldots,n. \qquad (5)$$

A quick way to verify that condition (5) is likely to be satisfied by the motor carrier market is to look at the many partnerships formed between shippers and carriers over the years. A partnership can be formed voluntarily only when the resulting service quality improvement brings net cost savings. Equation (5) can also be empirically verified. This is discussed in the next section.

Rewrite condition (5) and define x_k as follows:

$$a \ge \frac{c(t_k) - c(t_{k-1})}{q(t_{k-1}) - q(t_k)} = x_k, \qquad k = 2,3,\ldots,n. \qquad (6)$$

[1] A copy of the proof is available from the author on request.

Then, x_k is the ratio of the carrier's marginal cost increases over the shipper's service quality related cost savings if the transit time is reduced from t_{k-1} to t_k. Let $x = \max\{x_2, x_3,\ldots, x_n\}$. It follows from (6) that $a - x > 0$. Since y is within $[a, b]$, it follows that $y - x > 0$. The following will show that condition (6) restricts the number of competing carriers in a market.

Applying the Mean Value Theorem from standard calculus to the integration parts in (3) yields:

$$(y_{k+1} - y_k)w(y_k') = [p_k - c(t_k)]\left[\frac{w(y_{k+1})}{q(t_k) - q(t_{k+1})} + \frac{w(y_k)}{q(t_{k-1}) - q(t_k)}\right] \tag{7a}$$

where $y_k \le y_k' \le y_{k+1}$, $k = 2, 3,\ldots, n-1$,

$$(b - y_n)w(y_n') = \frac{[p_n - c(t_n)]w(y_n)}{q(t_{n-1}) - q(t_n)}, \quad k = n, \tag{7b}$$

where $y_n \le y_n' \le b$.

Denote $r_k = w(y_k)/w(y_k')$, $k = 2, 3,\ldots, n$. Since $y_k \le y_k'$, r_k is the weight density ratio of a low-valued shipment over a high-valued shipment. Consequently, if $w(y)$ is decreasing in y, r_k must be greater than 1. Let $r = \min\{r_2, r_3,\ldots, rn\}$.

Equation (7a) leads to:

$$(y_{k+1} - y_k)w(y_k') > \frac{[p_k - c(t_k)]w(y_k)}{q(t_{k-1}) - q(t_k)}, \quad k = 2,3,\ldots,n-1,$$

which is:

$$\begin{aligned}(y_{k+1} - y_k)w(y_k') &> \frac{[p_k - p_{k-1} + p_{k-1} - c(t_k)]w(y_k)}{q(t_{k-1}) - q(t_k)} \\ &= \left[y_k + \frac{p_{k-1} - c(t_k)}{q(t_{k-1}) - q(t_k)}\right]w(y_k) \\ &> \left[y_k + \frac{c(t_{k-1}) - c(t_k)}{q(t_{k-1}) - q(t_k)}\right]w(y_k) \\ &= (y_k - x_k)w(y_k)\end{aligned}$$

It follows that:

$$y_{k+1} - y_k > (y_k - x_k)r_k \ge (y_k - x)r$$

which is:

$$y_{k+1} - x > (1 + r)(y_k - x), \quad k = 2, 3,\ldots, n-1. \tag{8}$$

Following a similar procedure, it can be shown thatequation of (7b) leads to:

$$b - x > (1 + r)(y_n - x), \quad k = n \tag{9}$$

Combining (8) and (9) yields:

$$b - x > (1 + r)n - 1(y_2 - x) > (1 + r)^{n-1}(a - x),$$

since $y_2 > a$. Because $a - x > 0$, it follows that:

$$\frac{b - x}{a - x} > (1 + r)^{n-1}. \tag{10}$$

Equation (10) sets an upper bound on n, that is, in equilibrium, the number of carriers with positive market shares in a market cannot exceed the highest n given by (10). Note that the carriers with positive market shares are the ones with the high service qualities. Moreover, these carriers make positive profits, as indicated by the first-order condition (3). These results are contrary to the conventional perfect competition model. The conventional model predicts that, with a constant returns-to-scale cost structure, an infinite number of competitors can coexist in a market, each having an infinitely small but positive market share, and making zero profits.

The intuition behind (10) is straightforward. First of all, as implied by condition (5), the cost increases of providing high quality services are not beyond what shippers are willing to pay for the high quality services. Moreover, the rate competition among the carriers keeps their rates close to their respective costs. Consequently, even shippers with low-valued shipments choose the relatively high service quality carriers because the high service quality would bring them savings that would cover the rate increases. As a result, only a limited number of high service quality carriers can have positive market shares.

Now consider the case where some carriers have identical service qualities. It follows from the Bertrand type competition that these identical quality carriers in equilibrium would all set their rates at their (identical) marginal costs. This would cause carriers with lower service quality levels to lose their market shares because their shippers would find it cheaper to use the identical service quality carriers (see condition (5)). As a result, the identical service quality level effectively becomes the lowest level in the market. It follows that the number of carriers with distinctive and higher service qualities must be less than the upper bound minus one (one being the identical service quality). If the identical service quality level is the highest among all the quality levels in the market, it would be the only level left in the market. Note that the number of carriers with the identical service quality can be infinite. Under usual conditions, however, the case where the identical service quality is the highest and thus the only quality level in the market is not likely to be an equilibrium. This is because a carrier in the identical service quality group could be better off by slightly increasing its service quality so as to make positive profits.

4. Measuring the Upper Bound

This section estimates an upper bound on the number of carriers in the LTL motor carrier industry. Existing studies of shippers' service quality preferences indicate that the shipper's cost $q(t)$ is more sensitive to t than the carrier's marginal cost $c(t)$ is. See McGinnis (1990) for a review of such studies. Moreover, the recent empirical study by Allen and Liu (1992) has found that $c(t)$ decreases slightly as the carrier's output increases (that is, mild scale economies). This mild decrease of $c(t)$ is sufficient to cover its increase as the carrier's service quality increases. As a result, carriers with large output and high service quality usually operate at competitive or even lower marginal costs than carriers with small output and low service quality. In view of these facts, and following the

Table 2

Shipment Values per Unit Weight

Industry SIC Codes	*Shipment Values ($/lb)*	*Industry SIC Codes*	*Shipment Values ($/lb)*
20	0.358	30	1.057
21	1.705	31	3.014
22	1.322	32	0.068
23	3.852	33	0.306
24	0.067	34	0.733
25	1.085	35	2.493
26	0.323	36	2.861
27	0.977	37	1.536
28	0.301	38	3.731
29	0.058	39	1.765

Source: U.S. Department of Commerce (1981).

Table 3

Shipment Weight Distributions

Range of Shipment Values y	*Tons Shipped by Motor Carriers (1000 tons)*		*Weight Density w(y) (1000 tons² per $)*	
($/lb)	*Total Shipments*	*LTL Shipments*	*Total Shipments*	*LTL Shipments*
(1)	(2)	(3)	(4)*	(5)†
0.00-0.24	475582	9009	990.80	18.77
0.25-0.49	78872	11927	164.32	24.85
0.50-0.99	69394	17334	70.81	17.69
1.00-2.49	51237	21806	17.19	7.32
2.50-4.99	11352	5879	2.28	1.18
5.00-7.49	2301	1434	0.46	0.29
7.50-9.99	895	473	0.18	0.09
10.00-19.99	1049	644	0.05	0.03
Over 20.00	487	297	-	-

* (4) = (2)/(1)/2000, for example, 475582/0.24/2000 = 990.80
† (5) = (3)/(1)/2000, for example, 9009/0.24/2000 = 18.77
Source: U.S. Department of Commerce (1981).

definition of x_k by (6), it is reasonable to let $x_k = 0$, $k = 1,2,\ldots, n$. Condition (6) is thus satisfied and $x = 0$.

To have a measure of b/a and r, data from the 1977 Census of Transportation is used. There has been no freight flow data since then. The average shipment values per unit weight for each manufacturing industry group are shown in Table 2.

The highest shipment values are 3.852 for SIC 23 (apparel and other textile products) and 3.731 for SIC 38 (instruments and related products). The lowest ones are 0.058 for SIC 29 (petroleum and coal products), 0.067 for SIC 24 (lumber and wood products), and 0.068 for SIC 32 (stone, clay, and glass products). The ratio between the highest and lowest is approximately 66.

The weight density $w(y)$ for motor carriers is also computed from the Census data. It is shown in Table 3. In general, $w(y)$ decreases as y increases. For total shipments, this is the case for all the values of y. For LTL shipments, this is so for $y > 0.24$. Examination of more disaggregate Census of Transportation data and data from the Census of Manufactures has further confirmed this. Since condition (4) is satisfied by a wide range of distribution forms, it is reasonable to assume that $w(y)$ satisfies condition (4) and the existence of the rate equilibrium is ensured.

Given the decreasing feature of $w(y)$, it follows that most of the r_k's are larger than 1. Table 3 shows that, for LTL shipments, the smallest possible r is approximately given by $18.77/24.85 = 0.76$. For total shipments, r is greater than 1. The values $b/a = 66$ and $r = 0.76$ are used in (10) and the upper bound of n is found to be 8, since $(1.76)^8 > 66 > (1.76)^7$.

It is recognised that the data is highly aggregated and is taken from 1977. Different markets at different times have different values of x, b/a and r, and thus have different upper bounds on n. Nonetheless, the estimation points out that high concentration is the expected rule and the estimated upper bound, 8, is quite close to the number of dominant LTL carriers currently in large markets. Take California as an example. Currently, nine carriers cover 85 per cent of the market; the top two hold 35 per cent (Schulz, 1991). For the national and inter-regional market, the market shares of the top eight LTL carriers have steadily increased from 31 per cent in 1978 to 59 per cent in 1988 (Kling, 1990; Emerson, Grimm and Corsi, 1992). In 1990, the seventh and the twelfth largest LTL carriers went out of business. Currently, six large LTL carriers dominate this market.

5. Summary and Concluding Remarks

An equilibrium model is presented where carriers take their service quality levels as given and compete by choosing their rates. An upper bound on the number of competing carriers in a market is derived and empirically measured. The estimate closely resembles the current situation in LTL markets.

The model demonstrates that the high concentration in the LTL sector arises from the interaction between the shippers' service quality preferences and the carriers' cost structure. As indicated by the many shipper-carrier partnerships formed over the years, and the empirical studies of shippers' service quality preferences and LTL motor carriers' costs, the increased costs to carriers of providing high service quality are not beyond what

shippers are willing to pay for the high quality services. Moreover, the intense competition among the carriers has kept their rates close to their respective costs. Consequently, shippers would choose those relatively high service quality carriers because the high quality services would bring cost savings that would cover the rate increases. As a result, only a limited number of high service quality carriers have survived.

The model result and that of Allen and Liu (1993) imply that the frequently suggested differentiation strategy (for example, Smith, Corsi and Grimm, 1990) is not likely to alter the industry concentration. This strategy is necessary, but not sufficient. For a carrier to survive, its differentiated service quality must also be among the few high levels.

Attempting to save carriers from going bankrupt, a major LTL carrier group, the Regular Common Carrier Conference (RCCC), filed a petition with the Interstate Commerce Commission (ICC) in 1990, asking the ICC to impose a minimum rate standard (Abruzzese, 1990). The model can be used to show that this minimum rate policy would not be of much help. Simply replacing each carrier's marginal cost with the proposed minimum rate level, it is straightforward to show that the number of carriers would still be constrained by (10).

Finally, it is interesting to note that the model can be modified to examine the airline industry, which is going through a similar structural change (Liu and Bailey, 1993).

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Date of receipt of final manuscript: April 1993