PANZAR AND ROSSE STYLE TESTS OF MARKET STRUCTURE

IN THE U.S. MOTOR CARRIER INDUSTRY

By

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ABSTRACT

Panzar and Rosse tests for market structure, utilizing analysis of reduced form revenue equations, indicate that the trucking industry is not in long-run perfectly competitive equilibrium. However, it is ambiguous whether this is due to competitive disequilibrium or the existence of market power.

I. Introduction

The interstate trucking industry in the United States is estimated by the Federal Highway Administration to consist of about 260,000 firms. Table 1 shows the distribution of firm sizes based on author's calculations from information in the federal Motor Carrier Management Information System. While the vast majority of firms are very small, 5% of firms produce 70% of industry miles, with the top 86 firms accounting for 15% of output. It is an open question as to whether the extremely large firms are able to exert some market power in the face of considerable competition from numerous small firms.

TABLE 1: DISTRIBUTION OF FIRM SIZES

Number of Vehicles	% of Firms	% of Industry Mileage
1	42	3
2-3	28	7
4-6	14	7
7-11	8	7
12-20	4	7
21-1500	5	54
1500+	0.03	15

This question has challenged transportation economists in recent years. There is evidence that larger trucking firms have had greater commercial success than smaller trucking firms since deregulation. In work utilizing data primarily on the less-than-truckload (LTL) sector of the industry, Corsi *et al.* (3) found that larger firms earned higher profits than smaller firms, and Keeler (5) found evidence that the larger firms have been able to expand their market shares since deregulation at the expense of smaller firms. Kling (6) provides an excellent commentary, and calculates that the Hirschman-Herfindahl index of concentration for the LTL section increased from 200 in 1978 to nearly 600 in 1987.

However, this evidence of market power conflicts with the extensive literature on the relationship between trucking firm size and costs. Almost all of this literature, with the exception of Ying (11), concludes that there are no economies of scale in trucking, even within the LTL sector. Rakowski (9) believes that the apparent contradiction between the econometric cost studies and evidence of increasing market concentration is derived from "marketing economies." These accrue to large LTL firms who can provide high quality and comprehensive service to shippers at a competitive price by exploiting economies of scope and density. Keeler (5) argues that these marketing economies have not been captured in traditional cost function estimations, and applied a survivor-principle model to draw the inference that there are scale economies in truck transportation.

This paper approaches the same question from a different direction. The hypothesis of a perfectly competitive industry, which would be consistent with a constant cost industry, can be investigated using a test that involves estimation of coefficients on factor prices in reduced form revenue equations (8).

II. The Panzar and Rosse Test

Consider the following structural demand and cost relationships facing a trucking firm:

$$R = R(Y, H, X) \tag{1}$$

$$C = C(Y, H, W) \tag{2}$$

where: R = total revenue
C = total cost
Y = output
H = output attribute variables
X = exogenous demand variables
W = exogenous factor prices

Assuming that the output attribute variables are endogenously determined will give the following reduced form revenue equation:

$$R = R^{*}(W, X) \tag{3}$$

The Panzar and Rosse test is concerned with the sum of the elasticities of a firm's revenues with respect to factor prices (Ψ in their terminology) in reduced form equation 3.

Basic economic theory suggests values of Ψ that are consistent with different market structures. In particular Ψ will equal unity for perfect competition and will be negative in the case of monopoly. The intuition in the former case is that the perfectly competitive firm produces at the minimum point of its average cost curve. If all factor prices increase by 1%, the average cost curve will move up vertically as average cost is linearly homogeneous in factor prices. The output of the competitive firm will not change and, in equilibrium, price will increase to the new minimum point. Revenue will therefore also increase by 1%.

In the case of monopoly, elementary economics tells us that the monopolist will produce on the elastic portion of its demand curve. Any factor price increase will lead to a restriction of output and, by definition, a decline in total revenue.

Therefore two hypotheses can be tested on obtained values of Ψ. The first hypothesis test is the rejection of perfect competition by rejecting the null hypothesis that $\Psi = 1$. The second hypothesis test refutes monopoly by rejecting a null hypothesis that $\Psi < 0$. One should note that the tests are essentially of a negative nature in that the finding that Ψ=1 or Ψ<0 cannot be taken as definitive proof of perfect competition or monopoly respectively. Monopolistic competition can be consistent with both findings.

Of course, only the test of perfect competition is of practical relevance to the trucking industry. The other testable hypothesis, that of rejecting monopoly, may be relevant in other industries such as when investigating possible profit-maximizing collusion between firms, or whether there is effective competition from substitute products against an apparent monopolist (e.g., competition from trucks against a seemingly monopolistic regional railroad).

In his chapter on empirical tests for market power in the *Handbook of Industrial Organization*, Bresnahan (2) considered that this test held considerable promise for applied industrial economists. In particular the analyst need only know total firm revenues and does not require information on prices and output. In addition, there is no need to measure the often intangible differences in product quality across firms as quality is endogenous and hence does not appear in reduced form equations. As a result we avoid the problems discussed by Keeler (5) that result because traditional cost function analyses of the trucking industry have been unable to fully characterize the different output attributes between firms.

III. Data

Annual data were obtained on 85 firms for the six year period 1982 to 1987. Not all firms appeared in each year due to entry, exit, failure to submit required forms, or suspicious data. Consequently there are 473 useable observations. The firms are either class I or II Section 27 General Freight carriers, which means that they earn revenues of more than $1 million per annum and derive more than 75% of their revenues from the intercity transportation of general commodities. The data were obtained from tapes of the annual operating and financial statistics collected by the Interstate Commerce Commission, and processed and published by the American Trucking Associations (1).

Only the very largest firms are required to file data, and it is therefore reasonable to suppose that if any market power exists in the trucking industry it should be evident for these firms. The sample included the very large firms of Yellow Freight System Inc., Consolidated Freightways, and Roadway Express Inc. Given that much of the debate in the literature concerning apparent increasing market concentration has focused on the LTL sector of the market, we selected firms that derived at least 50% of revenues from LTL rather than truckload operations. In addition, we also required that the firms provide at least 85% of their mileage with their own vehicles rather than by sub-contractors. It is very difficult to discern accurately factor prices for firms who subcontract a large proportion of their mileage (see 4).

IV. Data and Variables

It is important that as many factor prices as possible are included, as an underlying assumption of the model is cost minimization and hence linear homogeneity. Factor prices were formulated for wages, fuel, sub-contracted mileage, capital, and vehicle taxes. These categories of costs represent 88% of the costs of a typical trucking firm (1). The full definition of the various factor prices is given below. All values were expressed in 1987 prices by inflating using the consumers' price index.

- Factor price of labor (WL): Estimated as the wages and salaries cost per employee.

- Factor price of capital (WK): Calculated as depreciation divided by net carrier operating property. This is a common price formulation used in the analysis of this industry (4).

- Factor price of purchased transportation. Subcontracting of work is very common. This can be either by engaging an owner-operator for some trips, where both the truck and the driver are rented, or by just renting the truck to be driven by a company driver. Factor prices for both types of subcontracting are employed: renting with driver (WS1) and without driver (WS2). In both cases the factor price is calculated by the total amount spent on that type of procurement divided by the number of vehicle miles rented. About half of the firms did not subcontract work, so the average price paid by firms who did subcontract that year was inserted for those firms.

- Factor price of fuel (WF): actual fuel expenditure per vehicle mile by trucks that a firm owns rather than rents.

- Factor price of operating taxes and licenses (WT): vehicle licenses and taxes divided by the number of trucks and tractors that a firm owns.

In addition an exogenous demand variable, Gross National Product per capita, was introduced into the reduced form equations. As the country moved out of the recession of the early 1980s, truck companies should have witnessed an increase in demand.

V. Estimation of Ψ

Previous estimations using the Panzar and Rosse test have used a log formulation of equation 3 (7,10). The theoretical foundation for this choice is that it can be derived from a Cobb-Douglas cost / production structure. A convenient way of calculating the Ψ statistic is to formulate the reduced form revenue equation with the logarithm of labor price subtracted from each of the other factor prices. Ψ is therefore the coefficient $ß_2$ in the following equation:

$$\ln(R) = ß_1\ln(GNP) + ß_2\ln(WL) + ß_3(\ln(WF) - \ln(WL)) + ß_4(\ln(WS1) - \ln(WL))$$
$$+ ß_5(\ln(WS2) - \ln(WL)) + ß_6(\ln(WK) - \ln(WL)) + ß_7(\ln(WT) - \ln(WL)) \quad (4)$$

Panel estimation techniques were used with fixed effects for each firm. The regression results are shown in table 2. Given the format of equation 4, only the coefficient $ß_2$ has a readily interpretable meaning. Ψ takes a value of 0.53 with a standard error of 0.12. Therefore perfect competition, and also monopoly, can be rejected. A Hausman test indicated that a fixed-effects model was preferable to a random-effects model, and an F test indicated that inclusion of the GNP and factor price variables was justified in addition to the firm specific fixed effects.

TABLE 2: REGRESSION ON LOGARITHM OF TOTAL REVENUE

Variable	Coefficient	Standard Error
Log of Gross National Product	1.0270	0.2206
Log of Labor Price	0.5298	0.1250
Log (Fuel Price / Labor Price)	0.0027	0.0542
Log (Rent with Driver Price / Labor Price)	-0.0013	0.0530
Log (Rent without Driver Price / Labor Price)	-0.0137	0.0227
Log (Capital Price / Labor Price)	0.0466	0.0196
Log (Taxes Price / Labor Price)	0.0787	0.0333
Number of Observations	473	
R^2 - fixed effects only	0.9933	
R^2 - fixed effects and variables	0.9946	
F test on inclusion of variables	13.17	
χ^2 of Hausman test of a fixed-effects versus random-effects model	43.06	

VI. Tests for Disequilibrium

Unfortunately, rejection of Ψ=1 does not necessary imply that the market is not inherently perfectly competitive. Short run disequilibrium in a perfectly competitive market is also consistent with this result. Consider the case where the average cost curve has "moved up" but price has yet to adjust to the new equilibrium. Shaffer (10) suggests a test for equilibrium. In a reduced form equation the return on assets (ROA) should be uncorrelated with input prices at equilibrium. In disequilibrium, the sum of ROA elasticities with respect to factor prices should be negative. The intuition is that in the disequilibrium situation described above, the increase in factor prices will lead to sub-normal profits until price adjusts.

Equation 4 was reestimated with ROA replacing revenue as the dependent variable. Return on assets was calculated by dividing operating profit by total firm assets. Assets are broadly defined to include cash and securities in addition to tangible equipment and premises.

A problem is that 20% of the observations had negative returns. Thus the log formulation requires that these observations are dropped from the dataset. These negative returns are spread quite widely across the firms in our sample, as only 5 firms recorded an operating loss in all, or almost all, years. The widespread existence of negative returns would in itself be *prima facie* evidence of disequilibrium. These firms are clearly not earning "normal profits" in these years, and the firms that earned negative returns for most or all of the years are probably considering exiting the industry.

The sum of the ROA elasticities with respect to factor prices, which will be termed Ψ', is estimated by coefficient $ß_2$. For the sake of space, only this estimated coefficient is reported in table 3. Unlike the previous regression, the Hausman test suggests that a random-effects model is preferable to a fixed-effects model. The former type of model is estimated using GLS. A hypothesis test that Ψ'=0, which indicates equilibrium, was conducted. Ψ' takes the value -1.35 with a standard error of 0.54. The hypothesis of equilibrium is rejected.

TABLE 3: TEST FOR DISEQUILIBRIUM

Ψ'	Coefficient	1.3449
	Standard Error	0.5436
Number of Observations		365
R^2		0.0658
χ^2 of Hausman test of a fixed-effects versus random-effects model		1.48

VII. Conclusions

The most useful conclusion is that the trucking industry cannot be modeled as a long-run perfectly competitive equilibrium. However, there is evidence both from the widespread incidence of firms earning negative returns, and our formal test that the market is in disequilibrium. Our analysis therefore gives the ambiguous result that the rejection of long-run perfect competition may be due to either temporary disequilibrium or else the existence of market power.

Readers may favor the latter explanation based on the strength of the rejection of perfect competition in our reduced form revenue equation, and the considerable anecdotal and analytical literature cited in the introductory section (3,5,6,9,11). Since deregulation, the larger firms in the LTL segment of the industry have increased their market share, and earned higher returns than smaller firms. Unfortunately, the Panzar and Rosse test is not useful in identifying other common theoretical market structures that might now characterize the industry, such as Cournot oligopoly or monopolistic competition. Other than rejecting the extremes of monopoly and perfect competition, one is not left any the wiser as to the appropriate economic model to build to describe the trucking industry.

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