Scale and Scope Economies of Intercity Coach Industry: Evidence from Taiwan

Ching-Fu Chen (Corresponding author)
Department of Transportation and Communication Management Science,
National Cheng Kung University,
1, University Rd., Tainan, 701, Taiwan.
Email: cfchen99@mail.ncku.edu.tw

Kwok Tong Soo
Department of Economics,
Lancaster University Management School,
Lancaster LA1 4YX, UK.
Email: k.soo@lancaster.ac.uk

Abstract

This paper investigates the cost structure and the scale and scope economies of the Taiwanese intercity coach industry after deregulation. Using a dataset of 37 firms between 2002 and 2006, a Pulley-Braunstein (1992) composite cost function is estimated together with the cost share equations, for two outputs and three inputs, using a Nonlinear Seemingly Unrelated Regressions (NLSUR) estimator. Our results show that there remain unexhausted scale economies in the Taiwanese intercity coach industry, and scope economies between the two outputs of motorway passenger services and regional road passenger services.

Keywords: scale economies, scope economies, composite cost function, intercity coach industry, Taiwan

September 2009
1. Introduction

Despite the rapid expansion of air travel and improvements in the technology of rail travel, the intercity coach industry remains an important part of the regional transportation system of a country. Because public transit industries are heavily regulated, there is often a wealth of information available on the underlying production technology of firms in the industry (Karlaftis and McCarthy, 2002). As a result, there has been much research on the cost structure and managerial efficiency of these industries (Berechman, 1987; Button and O’Donnell, 1985; Colburn and Talley, 1992; De Borger, 1984; De Borger, Kerstens and Costa, 2002; Fazioli and Filippini and Prioni; 1993; Filippini and Prioni, 2003; Gillen and Oum, 1984; Karlaftis and McCarthy, 2002; Obeng, 1985; Odeck, 2008, Viton, 1982; Williams and Hall, 1981). With increasing privatization of these industries, studies on the effects of privatization on public transit industries have grown. The empirical evidence from exploring the cost structure and related economic analyses can enable firms and policymakers to make informed decisions.

In this paper we investigate the intercity coach industry in Taiwan. The passenger services provided by this industry can be categorized into motorway and regional road services. In Taiwan, both motorway and regional road services were strongly regulated by their respective operation licenses in the past. In particular, the operation licenses of motorway passenger services were limited to a few main coach companies1. However, due to the gradual completion of the Taiwanese motorway network, the transport authority adopted

---

1 Initially, the intercity coach services were provided by the Taiwan Motor Transport Company (TMTC) in a monopoly since the 1980s. A partial deregulation policy implemented in 1996 resulted in a new legal entrant, Uni-Bus Company which had provided illegal intercity coach services before the partial deregulation. The TMTC has been privatized as the KKTC with the aim of improving its efficiency and performance and overcoming the risk of bankruptcy on July 1, 2001.
an open license policy in 1996 to allow coach companies (which initially operated regional road services or even local bus services) to apply for operating licenses of motorway services.

The number of companies offering motorway services therefore increased from 2 in 1996 to 26 in 2007, with most of the new entrants currently operating fewer than three routes. The market structure is basically an oligopoly dominated by 5 major companies. This liberalization is expected to enhance the service quality of intercity passenger services by introducing more competition on one hand, and allow coach companies to exploit the potential scale and scope economies as well as reduce operating costs by offering multiple services sharing to some extent the same operating resources. In addition, because many regional road passenger services are heavily dependent on government subsidies, government subsidies and fiscal burdens can be reduced if there are scale and scope economies from a multi-output coach company. Therefore, it is important for the transport authority to investigate the cost structure of the intercity coach industry and examine whether multi-output coach companies can utilize scope and scale economies to reduce their costs in comparison to those companies specialized in a single service.

The purpose of this study is to provide more insights about the cost structure of the intercity coach industry in Taiwan for evaluating the license deregulation policy in the intercity coach transport sector. In this paper, we empirically explore the evidence of scale and scope economies in 37 intercity coach companies operating in Taiwan from 2002 to 2006 by estimating a Pulley and Braunstein (1992) composite cost function. To our best knowledge, this is the first study applying the composite cost function to address the zero-output issue of the multi-output case in the context of passenger transport research outside the US and Europe. The results show that there remain unexhausted scale economies for the average firm in the Taiwanese intercity coach industry, and scope economies between
the two outputs of motorway passenger services and regional road passenger services. Nevertheless, larger firms experience much smaller scale and scope economies than smaller firms. These results may be of interest to both coach companies contemplating expansion, and policymakers who are deciding on the regulations surrounding the industry.

The rest of this paper is structured as follows. Section 2 reviews the related literature. Section 3 develops the theoretical model, while section 4 presents the concepts of scale and scope economies. Section 5 describes the data used and the estimation procedure. The empirical results and their implications are presented in Section 6. Finally, Section 7 summarizes the main conclusions.

2. Literature review

The economic analysis on public transit industries has been explored by a number of studies. By and large empirical studies are limited to the single-output case and focus on the issue of economies of scale and economies of density if the network effect is considered (Chiang Wang and Chen, 2005, De Borger et al, 2002, Filippini and Prioni, 1994, Fraquelli, Piacenza, and Abrate, 2004, Fraquelli et al. 2004, Karlaftis, 2001, Karlaftis and McCarthy, 2002, Karlaftis, McCarthy and Sinha,1999; Piacenza, 2006). Though economies of scale in public transit operations have been examined extensively in recent decades, there has been remarkably little consensus. In his recent study, Iseki (2008) reviews the relationship between the size of a transit system or agency and economies of scale, and summaries the diverse empirical evidences including economies of scale, diseconomies of scale and constant economies of scale found in past studies. In addition, he argues that the inconclusiveness of the debate over whether transit services experience economies of scale can be attributed to
several factors such as the assumption of a homogenous group of agencies and the specification of functional form.

Compared with the many studies associated with the single-output cost structure of bus companies, only a few studies, for example Colburn and Tally (1992), Di Giacomo and Ottoz (2008, 2009), Farsi et al. (2007), Gillen and Oum (1984) and Viton (1992), focus on the issue of multi-output production and scope economies. All of these studies that analyzed the long-run cost function of urban multi-mode transit system are in either the US or Europe. In terms of model specification, a translog cost function is adopted by Colburn and Tally (1992) whereas Gillen and Oum (1984) adopt a generalized translog cost function, and Viton (1992) and Farsi et al. (2007) employ a quadratic cost function. Di Giacomo and Ottoz (2008, 2009) are to the best of our knowledge the only papers using the Pulley and Braunstein (1992) composite cost function for the analysis of bus companies.\footnote{The applications of Pulley-Braunstein composite cost function can be found in other industries such as banking (Pulley and Braunstein, 1992, Adams, Bauer and Sickles, 2004), telecommunications (Bloch et al., 2001), public utilities (Fraquelli et al., 2004).}

Along with the estimation of multi-output cost function, in addition to the economies of scale, economies of scope is another important issue of economic analysis. Economies of scope exist if it is cheaper to produce more than one transit service in one company rather than in two specialized companies. Economies of scope could arise from sharing production activities of indivisible fixed costs that are not specific to each service and/or cost complementarity in production activities. Results from past studies in general give support to the existence of economies of scope in public transit industry. Empirical results of 289 urban transit companies operating in the US between 1984 and 1986 from Viton (1992) highlighted the presence of economies of scale and scope. Gillen and Oum (1984) reported unexploited scale economies and partial cost complementarity of a single urban multi-service company
from 1979-1988 in the US. Farsi et al (2007) examined the introduction of competitive
tendering procedures that allows companies to provide multi-mode services in the Swiss
urban public transport sector between 1985 and 1997 and found considerable economies of
scope and increasing returns to scale. Di Giacomo and Ottoz (2008, 2009), studying Italian
bus companies from 1998 to 2004, find evidence of scale and scope economies. Similarly to
these last two studies, the present study applies the Pulley-Braunstein composite cost function
to examine scale and scope economies of the Taiwanese intercity coach industry.

3. The Cost Function Model

We explore the properties of the cost function of Taiwanese intercity coach companies which
provide motorway and road passenger services. To deal with multi-product industries, the
flexible transcendental logarithmic (translog) function, introduced by Christensen et al.
(1973), is frequently adopted. However, if not all firms produce all outputs (i.e. when zero
outputs are present), the translog cost function cannot be implemented because the natural
logarithm of zero is not finite. To overcome this difficulty, some alternative functional forms
have been developed in the literature, such as the small value translog function, the
generalized translog multiproduct cost function (Caves, et al., 1980), the separable quadratic
specification (Baumol, Panzar and Willig, 1982), and the composite cost function (Pulley and
Braunstein, 1992).

The approach of the small value translog function is to insert a small positive value in
the place of zero outputs, and then apply the translog function to the modified function.
Despite its simplicity, the literature has identified a problem with the small value translog
function, relating to the erratic measures of scope economies generated by this method in
applied studies (Weninger, 2003). The generalized translog multiproduct cost function utilizes the Box-Cox transformation for outputs and the logarithmic transformation for input prices. Pulley and Braunstein (1992) find that empirically, the generalized translog function is a close approximation to the translog form, and therefore faces the same problems with estimating cost functions with zero outputs. The separable quadratic specification on the other hand has the disadvantage of imposing strong separability between outputs and inputs. The composite cost function utilizes a combination of a quadratic structure for outputs with a log-quadratic structure for input prices, and is designed to allow for the possibility of zero outputs, yet avoid the difficulties faced by the other functional forms. In this paper, we focus on and employ the composite cost function to deal with the zero-output case.

A firm’s cost function represents the firm’s cost-minimising choice of inputs to produce a given quantity of output, given input prices. The general form of the cost function for a firm with multiple inputs and outputs is:

\[ C(p, q) = \min_r p' r \text{ such that } T(r, q) = 0 \]  

(1)

Where \( p \) is a vector of input prices, \( q \) is a vector of outputs, \( r \) is a vector of inputs, and \( T(r, q) \) is the firm’s transformation function which shows the firm’s cost-minimising vector of inputs \( r \) to produce output \( q \). The Pulley and Braunstein (1992) composite cost function with multiple products and multiple inputs is:

\[
\ln C = \ln \left[ \alpha_0 + \sum_i \alpha_i q_i + \frac{1}{2} \sum_i \sum_j \alpha_{ij} q_i q_j + \sum_i \sum_k \delta_{ik} q_i \ln p_k \right] + \beta_0 + \sum_k \beta_k \ln p_k + \frac{1}{2} \sum_k \sum_k \beta_{kk} \ln p_k \ln p_l + \sum_i \sum_k \mu_{ik} q_i \ln p_k + u_{it} \]  

(2)

Where \( q_i \) denotes outputs, \( p_k \) denotes input prices and \( u_{it} \) is the error term. Following Pulley and Braunstein (1992), to avoid estimation problems, we drop \( \beta_0 \) and the terms involving \( \mu_{ik} \); this approach has been used by Pulley and Humphrey (1993) and Adams et al (2004).
Following Adams et al. (2004), we include a quadratic time trend to capture technological change. These changes result in equation (3):

\[ \ln C = \ln \left[ \alpha_0 + \sum_i \alpha_i q_i + \frac{1}{2} \sum_i \sum_j \alpha_{ij} q_i q_j + \varphi_1 T + \varphi_2 T^2 + \sum_i \sum_k \delta_{ik} q_i \ln p_k \right] + \]

\[ \sum_k \beta_k \ln p_k + \frac{1}{2} \sum_k \sum_l \beta_{kl} \ln p_k \ln p_l + u_{it} \]  
(3)

Where \( T \) is the time trend. For a cost function to be well behaved, it must satisfy the neoclassical conditions of being continuous, non-decreasing concave, symmetric, and homogeneous of degree one in input prices. The input price homogeneity (of degree one) restrictions are:

\[ \sum \beta_{ik} = 1, \quad \sum \beta_{kl} = \sum \beta_{lk} = \sum \delta_{ik} = 0 \]  
(4)

In addition, the symmetry restrictions across outputs and inputs are \( \alpha_{ij} = \alpha_{ji}, \beta_{kl} = \beta_{lk} \). All variables are divided by their respective sample means. By Shephard’s Lemma, the input cost share equations \( (S_n) \) corresponding to Eq. (3) are equal to the logarithmic partial derivatives of the cost function with respect to the input prices:

\[ S_k = \frac{\partial \ln C}{\partial \ln p_k} = \]

\[ \left[ \alpha_0 + \sum_i \alpha_i q_i + \frac{1}{2} \sum_i \sum_j \alpha_{ij} q_i q_j + \varphi_1 T + \varphi_2 T^2 + \right. \]

\[ \left. i k \delta_{ik} q_i \ln p_k - 1 i \delta_{ik} q_i + \beta_k + l \beta k \ln pl \right] \]

Where \( \sum S_k = 1 \).

4. Scale and Scope Economics

Following Baumol, Panzar and Willig (1982), global or aggregate scale economies in a multi-output setting is defined as:

\[ SL = \frac{C}{\sum_i q_i MC_i} = \frac{1}{\sum_i \varepsilon_{c_i q_i}} \]  
(6)

where \( MC_i = \partial C / \partial Q_i \) is the marginal cost of output \( i \) and \( \varepsilon_{c_i q_i} = \partial \ln C / \partial \ln q_i \) is the cost
elasticity with respect to output \( i \). Global scale economies describe the behaviour of costs due to a proportional change in all outputs of the firm. Returns to scale as defined by equation (4) are said to be increasing, constant or decreasing as \( SL \) is greater, equal to, or less than unity, respectively.

Scope economies exist when costs can be reduced by the joint production of multiple outputs. Following Baumol et al. (1982) the global or aggregate scope economies for a three-output case, for example, can be defined as the ratio of excess costs of separate production to the costs of joint production of all outputs:

\[
SC = \frac{C(q_1, 0, 0) + C(0, q_2, 0) + C(0, 0, q_3) - C(q)}{C(q)}
\] (7)

Scope economies (diseconomies) exist when \( SC \) is greater (less) than 0. To accommodate the zero-output case, Pulley and Braunstein (1992) propose the Quasi-scope economies (\( Q_{scope} \)) index:

\[
Q_{scope} = \frac{C([1 - (m - 1)\varepsilon]q_1, \varepsilon q_2, \ldots, \varepsilon q_m; p) 
+ \cdots + C(\varepsilon q_1, \varepsilon q_2, \ldots, [1 - (m - 1)\varepsilon]q_m; p)
- C(q_1, q_2, \ldots, q_m; p)}{C(q_1, q_2, \ldots, q_m; p)}
\] (8)

where \( m \) is the number of outputs and \( p \) is a vector of input prices. When \( \varepsilon = 0 \), then \( Q_{scope} \) is equivalent to the traditional measure of scope economies, i.e. \( SC \) in Eq. (7). The maximum value of \( \varepsilon \) is \( 1/m \). When \( Q_{scope} \) is greater than zero, therefore, it implies the existence of scope economies.

5. Data and Estimation Procedure
The sample used in this paper consists of 37 intercity coach companies in Taiwan. There are three major transport services offered by these companies: motorway passenger service, regional road passenger service and charter coach service. Table 1 shows that, on average, charter coach services contribute less than 3 percent to the total revenue of a coach company. Due to its negligible share compared to the other two services, charter coach service is excluded from the analysis. Hence, motorway passenger service and regional road passenger service are the two outputs considered in this study. Some companies offer only one of the two services.

The total cost function of the Taiwanese intercity coach industry is constructed with two outputs: motorway passenger service and regional road passenger service, and three inputs: labour, fuel and capital. In addition, a time trend (T) is employed to capture technological change. To reflect the fact that some outputs are zero, the composite cost function equation (3) is specified. The data over the period 2002-2006 are obtained from the National Federation of Bus Passenger Transportation Association of Republic of China. The data used in this study is an unbalanced panel consisting of 37 intercity coach companies over five years, totaling 160 observations.

The variables for the total cost function specification are defined and calculated as follows. The number of vehicle-kilometers is used as the output measure for motorway passenger service ($q_1$) and regional road passenger service ($q_2$). Since the cost function captures the cost of production, this is the appropriate output measure to use. We do not have data on seat-kilometers which would enable us to take into account the size of bus, and the use of passenger-kilometers as the output measure would confound both demand and supply.
side considerations, since passenger-kilometers may be driven by demand factors which are outside the control of the firm.\textsuperscript{3}

Labour price ($p_L$) is defined as the average annual wage per employee, and is measured by dividing the annual labour costs by the total number of full-time equivalent employees. Fuel price ($p_F$) is measured by dividing fuel costs by the total operated kilometers. Capital price ($p_K$) is obtained by dividing capital expenses by the total number of coaches in the operator’s fleet. Capital expenses are the sum of capital depreciation, maintenance cost, and administrative cost. Therefore, the price of capital captures not only the cost of coaches, but also all the overhead costs associated with running the bus company. The total cost ($C$) is defined as the sum of labour expenses, fuel expenses and capital expenses. Furthermore, the cost shares of labour ($S_L$), fuel ($S_F$) and capital ($S_K$) are defined as the ratio of labour expenses, fuel expenses and capital expenses to the total cost, respectively. Descriptive statistics of the variables are summarized in Table 1. All the costs and prices are adjusted for inflation using the consumer price index measured in 2002 NT$. Table 1 shows in particular that bus companies in Taiwan are different in size from each other, with total revenues ranging from 6 million NT$ to 3 billion NT$.

\textit{/ Table 1 inserted here/}

A system of three equations including cost, labour share and fuel share equations is estimated simultaneously using an iterated Nonlinear SURE (Seemingly Unrelated Regression) estimator which is the nonlinear counterpart of the Zellner’s (1962) iterated seemingly unrelated regression technique, with all symmetry and homogeneity constraints

\textsuperscript{3} The results using passenger-kilometers as the output measure are very similar to those using vehicle-kilometers.
discussed in Section 2 included. Since the sum of the factor cost-share equations is unity, however, the variance-covariance matrix would be singular. To overcome this, the cost share of capital is deleted from the system in this study. The estimates for the omitted equation can be obtained by using the adding-up constraints imposed in the model. NSURE is iterated until convergence to ensure that the estimates are invariant to which equation is dropped. The results reported are therefore maximum-likelihood results.4

6. Empirical Results

The estimates of the cost function and the basic statistics are reported in Table 2. The standard errors reported are clustered by firm to control for heteroskedasticity and serial correlation within firms. The uncentered R-squared of the cost function is 0.77, indicating that the model is a good fit to the data and explains a large proportion of the variation in costs. Turning to the parameter estimates, note that the first order coefficients represent the elasticity of cost with respect to the variables at the sample mean since the data are normalized by dividing by their respective means. As expected, all first-order output coefficients ($\alpha_1$ and $\alpha_2$) and those of the input price ($\beta_L$ and $\beta_F$)5 are positive and highly significant. Given the assumption of cost minimization, the required regularity conditions for a well-behaved cost function need to be satisfied. Since symmetry and homogeneity of degree one in factor prices restrictions are imposed on the system of equations, these conditions can be verified by checking the presence of non-negativity, concavity and monotonicity conditions (Berndt, 1991). Monotonicity is satisfied because the estimated marginal cost and

---

4 Since the dataset is a panel of firms over time, consideration was given to using panel data methods to estimate the model, to take into account the heterogeneity across firms. Firm-level fixed effects estimation was performed by taking deviations from the mean of each firm for all variables; however, the NSURE algorithm failed to converge when the variables were transformed in this way.

5 The coefficient $\beta_K$ may be obtained from the restrictions on input price homogeneity $\sum \beta_k = 1$ imposed in Eq. (2).
cost elasticity are positive. Since the predicted cost shares are positive, the non-negativity of the input prices is verified.

The first-order output coefficients show that marginal costs for motorway passenger service and regional road passenger service are 0.277 and 0.637, respectively. The marginal cost of regional road passenger is more than twice that of motorway passenger service, suggesting that the coach companies may benefit from increased provision in motorway passenger service. Except for motorway road passenger service, the second-order output coefficients are not significant. According to Bloch, Madden and Savage (2001), large second-order output elasticities imply that a one percent increase in output leads to an implausibly large change in the output cost elasticities, and suggest the fragility of the inferences of economies of scale and scope. The fact that we find small second-order output elasticities in this study means that our results do not face this problem.

The cost elasticities with respect to inputs reflect the influence of input price changes on total cost. For labour price, the cost elasticity or factor share ($\beta_L$) is 0.343, positive and significant. The cost elasticity with respect to fuel ($\beta_F$) is 0.238, positive and significant. Using the restriction of input price homogeneity, the cost elasticity with respect to capital is calculated as 0.419. In addition, the technological variable coefficient is not significant, i.e. $\varphi_T = 0.049$, indicating no evidence that costs change over time.

Based on the estimation results presented in Table 2, the economies of scale and scope (see Tables 3 and 4) are estimated using equations (6) and (7). Table 4 shows that the result for global scale economies (SL) is 1.33 for the median firm, indicating the presence of
increasing returns to scale in the Taiwanese intercity coach industry. This result also implies that scale economies are not fully exploited for all coach companies on average and an increase in each output can result in a reduction in unit operating cost. Additionally, evidence also shows that the degree of scale economies is increasing over time, i.e. global scale economies are rising from 1.01 in 2002 to 8.39 in 2006 in Table 3. There is also evidence in Table 4 that smaller firms at the first quartile of the distribution are in the region of greater scale economies, whereas larger firms at the third quartile of the distribution experience smaller scale economies. This suggests that the larger firms may be exhausting the scale economies in the industry, and that the industry does not tend towards a natural monopoly.

Turning to scope economies, the estimate of global scope economies (SC) for the median firm is 0.32, greater than zero and indicating the existence of scope economies. There is also evidence that scope economies are increasing over time. Larger firms have smaller scope economies than smaller firms; as with scale economies, this may indicate that the larger firms are exhausting the scope economies in the industry.

Since two outputs are specified in this study, the maximum value of $\varepsilon$, defined as $1/m$, is 0.5 when calculating the quasi-scope economies ($Q_{scope}$). The values of $\varepsilon$ of 0.05, 0.1, 0.15, 0.20, 0.25 and 0.30 are chosen for $Q_{scope}$ by using Equation (6). The different measures of $Q_{scope}$ represent the relative weights placed on each good, so for example $Q_{scope} -5\%$ means that cost of producing 5\% of motorway passenger service plus 95\% of regional road passenger service, and the cost of producing 95\% of motorway passenger service plus 5\% of regional road passenger service, are calculated and compared to the sum of costs of producing 100\% of each output. Various measures of $Q_{scope}$ in terms of output allocation are calculated to better characterize the scope economies. As shown in the second column of Table 3, $Q_{scope}$ is greater than zero for all values of $\varepsilon$, implying an efficiency gain from
jointly producing both outputs compared to producing them separately. In addition, the estimates of median Q_{scope} are to a large extent stable, ranging from 0.314 to 0.316 over various output allocation rates. Hence, economies of scope exist in the Taiwanese intercity coach industry. However, Q_{scope} decreases as firms become larger. Furthermore, the estimates of Q_{scope} are increasing over time, implying that the benefits obtained from less specialized provision are increasing over the period under study.

/Table 3 inserted here/

/Table 4 inserted here/

7. Conclusion

This paper examines the Taiwanese intercity coach industry from 2002 to 2006. We estimate the cost function of firms in this industry, taking special care on the issues of multi-output cost function estimation as well as scale and scope economies. A Pulley & Braunstein (1992) composite cost function is specified to explore the multi-output cost structure using a dataset of 37 intercity coach companies over the study period. The results reveal that there remain unexhausted scale economies for the average firm in the Taiwanese intercity coach industry, and scope economies between the two outputs of motorway passenger services and regional road passenger services. The increasing returns to scale imply that an increase in each output (i.e. vehicle-km) can contribute to a decrease in unit operating cost for the coach companies on average. Furthermore, the presence of scope economies indicates that multi-output production is more efficient than separate specialized output production. Nevertheless, our results also show that larger firms at the third quartile of the size distribution have exhausted the scale and scope economies which are much stronger for smaller firms.
Facing the shift in consumer preferences towards more automobile usage and competition from other modes of travel such as high speed rail, the trend of decreasing intercity coach passenger demand is inevitable. Hence, attracting more passengers to choose coach services, either motorway services or regional road services, is a big challenge for firms in the industry. Our results suggest several possible ways that firms may respond to these economic conditions. Given unexploited scale economies and the presence of scope economies, smaller firms may benefit from providing both motorway and regional road services or forming collaborative joint ventures through joint utilization of inputs such as labour, capital and energy, similar skills such as driving, management and maintenance, or common activities such as advertising, scheduling and ticketing (Farsi et al., 2007). Also, since the estimated marginal cost of regional road services is more than twice that of motorway services, it may be possible for coach companies to reduce costs by re-allocating their output shares between the two services. In other words, strategies like expanding from regional road service to motorway service or increasing output in motorway service are likely to reduce the total costs and hence improve productivity.

In terms of government policy, that most of the companies in our dataset produce both services, to some extent reflects the effects of the license deregulation policy for intercity coach operations. As expected, firms responded to the presence of scale and scope economies by entering the motorway services sector once the open licensing policy on motorway services was adopted. As the demand for the industry shrinks in the future, given the large current number of firms, competitive pressures may lead to the merger or acquisition of firms, as this may improve the financial viability of the industry. The government may wish to consider further deregulation to increase competition within the industry, which may lead smaller firms to take steps to further exploit the scale and scope economies that are available.
This need not necessarily raise the danger of natural monopolies forming, since the results of this study suggest that larger firms do not experience the same degree of scale and scope economies as do smaller firms.
References


Table 1 Descriptive statistics of the data (n = 160)

<table>
<thead>
<tr>
<th>Variable</th>
<th>Obs</th>
<th>Mean</th>
<th>Std. Dev.</th>
<th>Min</th>
<th>Max</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total revenue</td>
<td>Million NT$</td>
<td>538.02</td>
<td>681.53</td>
<td>6.64</td>
<td>3316.64</td>
</tr>
<tr>
<td>Motorway revenue</td>
<td>Million NT$</td>
<td>234.98</td>
<td>619.98</td>
<td>0.00</td>
<td>3215.45</td>
</tr>
<tr>
<td>Regional road revenue</td>
<td>Million NT$</td>
<td>120.24</td>
<td>152.15</td>
<td>0.00</td>
<td>689.70</td>
</tr>
<tr>
<td>Bus revenue</td>
<td>Million NT$</td>
<td>170.60</td>
<td>354.28</td>
<td>0.00</td>
<td>1485.43</td>
</tr>
<tr>
<td>Charter revenue</td>
<td>Million NT$</td>
<td>12.42</td>
<td>22.78</td>
<td>0.00</td>
<td>114.45</td>
</tr>
<tr>
<td>Total cost (C)</td>
<td>Million NT$</td>
<td>570.63</td>
<td>655.73</td>
<td>13.43</td>
<td>3061.35</td>
</tr>
<tr>
<td>Motorway vehicle km (q1)</td>
<td>Million</td>
<td>11.08</td>
<td>31.97</td>
<td>0.00</td>
<td>203.00</td>
</tr>
<tr>
<td>Regional road vehicle km (q2)</td>
<td>Million</td>
<td>5.36</td>
<td>6.17</td>
<td>0.00</td>
<td>28.00</td>
</tr>
<tr>
<td>Motorway passenger km</td>
<td>Million</td>
<td>196.14</td>
<td>554.23</td>
<td>0.00</td>
<td>2972.58</td>
</tr>
<tr>
<td>Regional road passenger km</td>
<td>Million</td>
<td>60.03</td>
<td>79.42</td>
<td>0.00</td>
<td>402.94</td>
</tr>
<tr>
<td>Labour price (pL)</td>
<td>NT$/employee</td>
<td>473064</td>
<td>181545</td>
<td>6847</td>
<td>1226329</td>
</tr>
<tr>
<td>Fuel price (pF)</td>
<td>NT$/km</td>
<td>5.004</td>
<td>2.997</td>
<td>0.390</td>
<td>36.803</td>
</tr>
<tr>
<td>Capital price (pK)</td>
<td>NT$/coach</td>
<td>853135</td>
<td>473844</td>
<td>32302</td>
<td>3304023</td>
</tr>
<tr>
<td>Share of labour cost (SL)</td>
<td></td>
<td>0.384</td>
<td>0.106</td>
<td>0.005</td>
<td>0.573</td>
</tr>
<tr>
<td>Share of fuel cost (SF)</td>
<td></td>
<td>0.216</td>
<td>0.084</td>
<td>0.049</td>
<td>0.800</td>
</tr>
<tr>
<td>Share of capital (SK)</td>
<td></td>
<td>0.399</td>
<td>0.101</td>
<td>0.035</td>
<td>0.830</td>
</tr>
<tr>
<td>No. of employees</td>
<td></td>
<td>447.76</td>
<td>465.06</td>
<td>11.00</td>
<td>1946.00</td>
</tr>
<tr>
<td>No. of coaches</td>
<td></td>
<td>264.19</td>
<td>241.56</td>
<td>10.00</td>
<td>1132.00</td>
</tr>
<tr>
<td>Fuel cost</td>
<td>Million NT$</td>
<td>117.07</td>
<td>151.10</td>
<td>2.14</td>
<td>854.43</td>
</tr>
<tr>
<td>Labour cost</td>
<td>Million NT$</td>
<td>230.97</td>
<td>262.13</td>
<td>1.12</td>
<td>1083.22</td>
</tr>
<tr>
<td>Maintenance cost</td>
<td>Million NT$</td>
<td>24.36</td>
<td>28.69</td>
<td>0.22</td>
<td>164.20</td>
</tr>
<tr>
<td>Administrative cost</td>
<td>Million NT$</td>
<td>111.97</td>
<td>135.09</td>
<td>0.36</td>
<td>676.76</td>
</tr>
<tr>
<td>Depreciation cost</td>
<td>Million NT$</td>
<td>86.45</td>
<td>109.07</td>
<td>0.00</td>
<td>544.08</td>
</tr>
</tbody>
</table>
Table 2 Parameter estimates and basic statistics for the composite cost function

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Variables</th>
<th>Estimates</th>
<th>Robust S.D.</th>
<th>Robust z value</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\alpha_0$</td>
<td>Constant</td>
<td>-0.022</td>
<td>0.137</td>
<td>-0.16</td>
</tr>
<tr>
<td>$\beta_L$</td>
<td>ln$p_L$</td>
<td>0.343***</td>
<td>0.019</td>
<td>17.89</td>
</tr>
<tr>
<td>$\beta_F$</td>
<td>ln$p_F$</td>
<td>0.238***</td>
<td>0.019</td>
<td>12.64</td>
</tr>
<tr>
<td>$\alpha_1$</td>
<td>$q_1$</td>
<td>0.277***</td>
<td>0.101</td>
<td>2.74</td>
</tr>
<tr>
<td>$\alpha_2$</td>
<td>$q_2$</td>
<td>0.637***</td>
<td>0.173</td>
<td>3.69</td>
</tr>
<tr>
<td>$\beta_{LL}$</td>
<td>ln$p_L \cdot ln_p_L$</td>
<td>0.109***</td>
<td>0.009</td>
<td>11.79</td>
</tr>
<tr>
<td>$\beta_{FF}$</td>
<td>ln$p_F \cdot ln_p_F$</td>
<td>0.098***</td>
<td>0.019</td>
<td>5.19</td>
</tr>
<tr>
<td>$\beta_{LF}$</td>
<td>ln$p_L \cdot ln_p_F$</td>
<td>-0.038***</td>
<td>0.014</td>
<td>-2.64</td>
</tr>
<tr>
<td>$\alpha_{11}$</td>
<td>$q_1 \cdot q_1$</td>
<td>-0.082**</td>
<td>0.037</td>
<td>-2.25</td>
</tr>
<tr>
<td>$\alpha_{22}$</td>
<td>$q_2 \cdot q_2$</td>
<td>0.009</td>
<td>0.026</td>
<td>0.36</td>
</tr>
<tr>
<td>$\alpha_{12}$</td>
<td>$q_1 \cdot q_2$</td>
<td>-0.002</td>
<td>0.006</td>
<td>-0.36</td>
</tr>
<tr>
<td>$\delta_{L1}$</td>
<td>ln$p_L \cdot q_1$</td>
<td>0.005</td>
<td>0.008</td>
<td>0.68</td>
</tr>
<tr>
<td>$\delta_{L2}$</td>
<td>ln$p_L \cdot q_2$</td>
<td>0.044***</td>
<td>0.013</td>
<td>3.26</td>
</tr>
<tr>
<td>$\delta_{F1}$</td>
<td>ln$p_F \cdot q_1$</td>
<td>0.013*</td>
<td>0.007</td>
<td>1.86</td>
</tr>
<tr>
<td>$\delta_{F2}$</td>
<td>ln$p_F \cdot q_2$</td>
<td>-0.041***</td>
<td>0.013</td>
<td>-3.24</td>
</tr>
<tr>
<td>$\phi_T$</td>
<td>$T$</td>
<td>0.049</td>
<td>0.173</td>
<td>0.29</td>
</tr>
<tr>
<td>$\phi_{TT}$</td>
<td>$TT$</td>
<td>0.014</td>
<td>0.031</td>
<td>0.44</td>
</tr>
</tbody>
</table>

Number of observations 160
Log likelihood 316.39
Uncentered R-squared 0.7684

Notes:
1. * significant at 10%; ** significant at 5%; *** significant at 1%. Heteroskedastic-robust standard errors clustered by firm reported. Estimation method is Nonlinear SURE with the feasible GLS estimates iterated until convergence is achieved.
2. White test statistic: 1.91 (p-value = 0.1518).
Table 3: Estimates of global scale, global scope and quasi-scope economies over time, median firm.

<table>
<thead>
<tr>
<th></th>
<th>2002</th>
<th>2003</th>
<th>2004</th>
<th>2005</th>
<th>2006</th>
</tr>
</thead>
<tbody>
<tr>
<td>Global scale economies</td>
<td>1.014</td>
<td>1.107</td>
<td>1.313</td>
<td>1.524</td>
<td>8.388</td>
</tr>
<tr>
<td>Global scope economies</td>
<td>0.071</td>
<td>0.169</td>
<td>0.278</td>
<td>0.400</td>
<td>0.892</td>
</tr>
<tr>
<td>Qscope. 5%</td>
<td>0.070</td>
<td>0.169</td>
<td>0.277</td>
<td>0.400</td>
<td>0.892</td>
</tr>
<tr>
<td>Qscope. 10%</td>
<td>0.069</td>
<td>0.168</td>
<td>0.277</td>
<td>0.400</td>
<td>0.892</td>
</tr>
<tr>
<td>Qscope. 15%</td>
<td>0.069</td>
<td>0.168</td>
<td>0.277</td>
<td>0.400</td>
<td>0.892</td>
</tr>
<tr>
<td>Qscope. 20%</td>
<td>0.068</td>
<td>0.167</td>
<td>0.276</td>
<td>0.400</td>
<td>0.892</td>
</tr>
<tr>
<td>Qscope. 25%</td>
<td>0.068</td>
<td>0.167</td>
<td>0.276</td>
<td>0.400</td>
<td>0.892</td>
</tr>
<tr>
<td>Qscope. 30%</td>
<td>0.068</td>
<td>0.167</td>
<td>0.276</td>
<td>0.400</td>
<td>0.892</td>
</tr>
</tbody>
</table>

Table 4: Estimates of global scale, global scope and quasi-scope economies for firms at the median, first and third quartiles.

<table>
<thead>
<tr>
<th></th>
<th>1st quartile</th>
<th>Median</th>
<th>3rd quartile</th>
</tr>
</thead>
<tbody>
<tr>
<td>Global scale economies</td>
<td>23.150</td>
<td>1.332</td>
<td>1.099</td>
</tr>
<tr>
<td>Global scope economies</td>
<td>0.961</td>
<td>0.317</td>
<td>0.172</td>
</tr>
<tr>
<td>Qscope. 5%</td>
<td>0.961</td>
<td>0.316</td>
<td>0.171</td>
</tr>
<tr>
<td>Qscope. 10%</td>
<td>0.961</td>
<td>0.316</td>
<td>0.171</td>
</tr>
<tr>
<td>Qscope. 15%</td>
<td>0.961</td>
<td>0.315</td>
<td>0.170</td>
</tr>
<tr>
<td>Qscope. 20%</td>
<td>0.961</td>
<td>0.315</td>
<td>0.170</td>
</tr>
<tr>
<td>Qscope. 25%</td>
<td>0.961</td>
<td>0.315</td>
<td>0.169</td>
</tr>
<tr>
<td>Qscope. 30%</td>
<td>0.961</td>
<td>0.314</td>
<td>0.169</td>
</tr>
</tbody>
</table>