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Abstract

The purpose of this study is to analyze the cost structure of a sample of Swiss multi-modal urban transport operators in order to assess economies of scale and scope. The results suggest that the industry is characterized by increasing returns to scale and economies of scope. Several European countries have introduced a competitive tendering procedure in the assignment of franchised monopoly in the local transport industry. In the case of multi-modal systems the regulator has to decide to open the competitive tendering procedure for supplying the entire transport services or to unbundle the multi-modal systems and open separate tenders for different modes of transport. In order to make the decision the regulator should have information on the economies of scope. Only few studies have addressed the issue of scope economies in local transport systems.

1. Introduction

During the last two decades several EU-member countries have introduced a competitive tendering procedure in the assignment of franchised monopolies in the local transport industry. This process has been initiated by the European Directive 1191/69/EU (modified by 1893/91/EU) that requires the member countries to use competitive tenders in cases where the providers are not owned by home states. The implementation of tendering procedures in the urban transit industry is, however, not straightforward, because in many cases the incumbents are large multi-modal transit operators that combine different transport systems such as motor-bus, tramway and trolley-bus. In such cases the local authorities could hold a competitive tendering procedure for supplying the entire transport services, or unbundle the multi-modal systems and open separate tenders for different modes of transport.

When transport modes are legally unbundled, bidding can be opened to both single-mode operators and multi-mode companies. Whereas in the present situation the competition is difficult for companies specialized in a single transit service because of the comparative advantage of the incumbent multi-mode companies. In this case, due to fewer potential bidders, the benefits from competition for the market would be lower.¹ On the other hand, a single multi-mode transit company can exploit the potential scope and scale economies. It should be noted that such synergies cannot be completely used even if the different single-mode units are owned by a single owning company. Therefore, legal unbundling suffices to remove the entry barrier for single-mode operators but does not guarantee the use of scale and scope economies.

The choice between these two tendering options is an important policy question that has extremely important impacts on the organization of the local transport system namely, the operation mode (single or multiple) in different parts of a network as well as the planning of final services such as frequencies, number of lines etc. Therefore, it is relevant for the local authorities to know if and how much a multi-mode supplier could use the scope and scale economies to reduce their costs in comparison to a group of single-mode operators. This question is in line with the

¹ For a discussion of the problems in the application of competitive tendering processes in the local transport sector see Cambini and Filippini (2003).

important issue of natural monopoly raised by Baumol, Panzar et al. (1982), applied to the local transport sector.

In the presence of economies of scope a multi-output firm is more economical than separate specialized firms. Following Baumol, Panzar et al. (1982) and Bailey and Friedlaender (1982) the scope economies can result from sharing or the joint utilization of inputs. In the case of local public transportation such sharable inputs are labor, capital and energy. Local public transport companies which combine several transport modes use similar equipment such as wires, overhead line and similar skills such as driving, management and network maintenance. Such synergies also apply to activities like R&D, advertising and ticketing. Another source of cost savings is due to economies of massed reserves (Waldman and Jensen (2001)). Multi-output transportation companies can make use of the same reserve capacity for maintenance and buildings.

Most of the local transport companies in Switzerland participate in a transportation network. These networks can be only tariff networks but also more complex networks where the network company purchases the services delivered by the transportation companies is also responsible for advertising, ticketing and customer services. This means that some common activities are already centralized.

The purpose of this study is to make a contribution to the above debate on the introduction of competitive tendering procedures in the urban bus transportation sector. This paper explores the empirical evidence of scale and scope economies in 16 multi-mode transport companies operating in Switzerland from 1985 to 2003. A total cost function with quadratic form has been estimated. The results suggest that scope economies exist for at most of the output levels observed in the data. This study provides some evidence in favor of the status quo regarding multi-mode transport companies. The potential competition benefits of unbundling remain to be explored.

The rest of the paper proceeds as follows: Section 2 provides a brief review of the relevant literature and presents the adopted specification. The data are described in section 3. Section 4 presents the estimation results and discusses their implications. The main conclusions are summarized at the end.

2. Model specification and econometric methods

There is a great body of literature on the cost structure of single output bus companies. Filippini and Prioni (1994), Fraquelli, Piacenza et al. (2004a), Wang-

Chiang and Chen (2005) and Farsi, Filippini et al. (2006) are among the recent empirical examples. However, only a few studies have addressed the issue of scope economies in urban transit systems. Authors such as Gillen and Oum (1984) studied companies operating with a single transport mode but in a multi-product set-up. In these cases the multiple outputs are defined on the basis of service type namely, urban, intercity etc. Previous studies on the economies of scope across different modes of transport (such as motor-bus, tramway, and trolley-bus) are rare and mostly outdated. The most relevant ones in this category are Viton (1992), Viton (1993) and Colburn and Talley (1992), both of which analyzed the long run cost structure of urban multi-mode transit system in the U.S.

Viton (1992) studied the cost structure of a sample of 289 urban transit companies operating in the U.S. between 1984 and 1986. Six modes are distinguished: motor-bus, rapid-rail, streetcar, trolley-bus, demand responsive mode and a last mode including all other modes. Viton uses a quadratic total cost function with the following explanatory variables: six outputs, measured in vehicles-miles, price of labor and the average speed in each one of the six modes. Empirical results highlight the presence of economies of scale and scope. However, the extent of the economies of scope depends on the post-consolidation level of the wage: If wages remain unchanged after consolidation, economies of scope exist for certain transportation modes. If, on the other hand, wages rise due to consolidation, economies of scope are smaller or even negative. Colburn and Talley (1992) analyze the economies of scale and scope of a single urban multi-service company using quarterly data from 1979 to 1988. Four modes are distinguished: motor-bus, dial-a-ride, elderly service, and van pool service. Colburn and Talley used a translog total cost function with the following explanatory variables: four outputs, measured in vehicles-miles, and three factor prices (labor, fuel and capital). The empirical results reported in that study indicate unexploited scale economies. However, the evidence of cost complementarity is limited to certain combinations involving motor-bus and the three para-transit services (elderly service, and van pool service).

In this paper we consider three modes that are typically used in most European urban transit systems namely, motor-bus, trolley-bus and tramway. We will employ a panel data econometric approach. To our knowledge this paper is the first empirical study of a European urban transit system that provides evidence about the economies of scale and scope across transport modes.

The model specification is based on a cost function with three outputs namely, transport services in three modes and two inputs, labor (L) and capital (K). The network size is also included in the model. Network size can be defined, for instance, by the number of stops. If it is assumed that the firm minimizes cost and that the technology is convex, a total cost function can be written as:

$$C = C(y^{(1)}, y^{(2)}, y^{(3)}, w^{(1)}, w^{(2)}, n, t) \quad (1)$$

where C represents total costs; $y^{(1)}$, $y^{(2)}$ and $y^{(3)}$ are the numbers of seat-kilometers provided by trolley-bus, motor-bus and tramway systems respectively; and $w^{(1)}$ and $w^{(2)}$ are the factor prices for labor and capital respectively. The largest fraction of total costs is for labor costs (61% on average). Capital price includes also material costs and energy costs².

The size of the network (n) is measured by the number of stops³ and t is the linear trend which captures the shift in technology representing technical change.

Following Baumol, Panzar et al. (1982) and Mayo (1984) we use a quadratic cost function.⁴ Unlike logarithmic forms, this functional form accommodates zero values for outputs thus, allows a straightforward identification of scope economies. Although logarithmic functions could be used with an arbitrary small value transformation for zero values, it has been shown that this approach could result in large errors in the estimation of scope economies (Pulley and Humphrey (1993)). As in our case, many output values for trolley-buses and tramways are zero, such estimation errors may lead to misleading conclusions about scope economies. However, one disadvantage of the quadratic form is that the linear homogeneity of the cost function in input prices cannot be imposed.

² The energy price is not included directly as energy costs are only a small fraction of total costs (with a mean of 3.4% and less than 6.3% for 95% of all observation) and as it does not vary a lot over time. Furthermore the three modes have different energy sources which are measured in different units (kWh and litres). Trolley-buses and tramways both use electricity whereas motor-buses use diesel or gas.

³ In two alternative specifications we respectively used area size and network length (sum of the three modes) instead of number of stops. Neither variable has shown any statistically significant effect at 5% significance level. This can be partly explained by relatively high density variation within a service area and also variation of shape and complexity across different networks.

⁴ A quadratic function requires an approximation of the underlying cost function at a local point, which in our case is taken at the sample mean. Thus, all independent variables are normalized by their mean point.

The cost function specification can therefore be written as follows:

$$C_{it} = \alpha_0 + \sum_m \alpha^m y_{it}^{(m)} + \frac{1}{2} \sum_m \sum_n \alpha^{mn} y_{it}^{(m)} y_{it}^{(n)} + \sum_p \beta^p w_{it}^{(p)} + \alpha^n n_{it} + \alpha^t t_t + \varepsilon_{it} \quad (2)$$

where superscripts m and p denote respectively, the number of products (1, 2, 3) and the number of input factors (1, 2), subscript i and t denote respectively, the company and subscript t the period. Variable y is a product quantity, w is a factor price, t is a time trend and n is a network characteristic. The factor prices and the network variable are introduced in a linear way (following Mayo (1984) and Viton (1992), respectively).

The econometric model [2] is estimated for an unbalanced panel data set consisting of 16 companies over 19 years (300 observations). The repeated observations of a same company allow the use of panel data models that can account for unobserved heterogeneity across companies. However, as the number of companies is smaller than the number of periods ($N < T$), this data set is an unusual case for widely used panel data specifications such as fixed effects and random effects models, in which T is small relative to N .⁵ When sample period is relatively short, one can assume that the individual effects remain constant. In long panel data on the other hand these effects might change over time, resulting in serial correlation of errors.⁶ Both fixed and random effects models can be extended to include serial correlations with an autoregressive model of order 1 as in Cochrane-Orcutt approach (Cochrane and Orcutt (1949)). However, given the small size of the sample, a pooled model seems adequate for our purpose. Given the relative importance of between variations (variations among companies) in our sample we decided to exclude the fixed and random effects models that rely on within variations (changes within companies) and exclude most of the between variations as company-specific residuals.

For the above reasons, we decided to pool the data across different companies and use a heteroscedastic model with autoregressive errors, as proposed by Kmenta (1986).⁷ The Kmenta approach, also known as the cross-sectionally heteroscedastic

⁵ For a detailed presentation of panel data models, see Greene (2003) and Baltagi (2001).

⁶ The significant test statistics from autocorrelation test in panel data (Wooldridge (2002)) indicates the presence of serial correlation in the data.

⁷ Model [2] has been also estimated using the fixed and random effects approaches. Generally, the estimated coefficients are similar to those obtained using the Kmenta approach. In the fixed effects model the coefficient of the network variable is negative. This counterintuitive sign could be due to the fact that the within variation of the explanatory variable is very low.

and time-wise autoregressive model, is attractive when N , the number of units, is lower than T , the number of periods, or when the within variation of many explanatory variables is very low. In this model, the cross-sectional heteroscedasticity captures the unobserved heterogeneity across companies,⁸ while the serial correlation is modeled through the autoregressive error structure as follows:

$$\varepsilon_{it} = \rho_i \varepsilon_{i,t-1} + u_{it} \quad (\text{autoregressive errors})$$

$$E(u_{it}^2) = \sigma_i^2 \quad (\text{heteroscedasticity})$$

where ρ_i is a coefficient of first-order autocorrelation. It is assumed that the correlation parameter is firm specific. The Kmenta method consists of two sequential feasible generalized least squares (FGLS) transformations to remove autocorrelation and cross-sectional heteroscedasticity respectively (Baltagi (2001), Kmenta (1986)).

3. Data

The sample consists of 16 companies which all have more than one type of vehicle mode. For the years 1985 – 1997 the yearly data are from the annual statistics on public transport from the Swiss Federal Statistical Office BFS (1985-97). For the years 1998–2003 the data are taken from annual reports as the former publication is published only in an aggregated way. Because of a merger with a regional transportation company, one company was dropped from 1999. Six firms offer all three modal transit services, nine motor-bus and trolley-bus services and one trolley-bus and tramway services.

The firm information that is available in the dataset includes costs, total number of employees, network length, total numbers of trolley-buses, motor-buses and tramways, vehicle-kilometers, delivered passengers and total number of seats per transportation mode.

The variables for the cost function specification were calculated as follows. Total costs (TC) are calculated as the total expenditures of the local public transit firms in a given year. The output y is measured by the number of seat-kilometers provided by motor-buses, trolley-buses and tramways, respectively. This is a pure

⁸ A modified Wald test on an OLS model shows the existence of heteroscedasticity in our data.

supply output measures. In studies by Fazioli, Filippini et al. (1993), Farsi, Filippini et al. (2006) seat-kilometers was taken as the output for the estimation of a costs function for bus companies. Filippini and Prioni (2003) compared a model with bus-kilometers with one with seat-kilometers as output. The output variable bus kilometers has the disadvantage that the size of the bus is not taken into account. Alternatively some authors have used passenger revenue (as in Button and O'Donnell (1985)) or passenger trips (Berechman (1987), Bhattacharyya, Kumbhakar et al. (1995), Windle (1988)).

Input prices are defined as factor expenditures per factor unit. Labor price (w_1) is defined as the ratio of annual labor costs to the total number of employees. Following Friedlaender and Wang Chiang (1983), the capital price (w_2) is calculated as residual cost (where residual cost is total cost minus labor) divided by the total number of seats in the operator's fleet.⁹ Unfortunately no data were available which would allow us to calculate the capital stock using the capital inventory method. The use of a simple indicator is justified by the fact that the bus companies do not possess a significant stock of capital apart from the rolling stock. All the costs and prices are adjusted for inflation using the Switzerland's consumer price index and are measured in year 2000 Swiss Francs (CHF).

Table 1 shows the descriptive statistics. As there were only six and from 1991 on only seven companies out of 16 which offer tramways services, we see from the table that the median output of the tramways is zero and that the 3rd quartile output is smaller than the mean output.

Table 1: Descriptive statistics (300 observations)

		Min.	1st Quartile	Median	Mean	3rd Quartile	Max.	Std. dev.
Output [Mio seat-kilometres]	Trolley-bus	0	79	176	249	368	861	212
	Motor-bus	32	93	181	334	343	1'614	401
	Tramway	0	0	0	365	335	2'926	745
Total cost [Mio CHF]		8.22	18.23	30.98	79.32	108.93	430.39	97.92
Labour price [CHF per employee]		39'888	85'585	93'330	90'942	99'321	123'861	12'317
Capital price [CHF per seat]		492	1'117	1'357	1'413	1'612	3'128	410
Number of stops		64	141	186	246	278	772	163

⁹ For an application of this approach in the bus industry see Filippini and Prioni (2003) and Farsi, Filippini et al. (2006).

4. Results

The estimation results are given in Table 2. The results show that the output and input price coefficients have the expected positive sign and that they are highly significant. The cost function is concave in outputs as α^1 , α^2 and α^3 are positive and the quadratic terms α^{11} , α^{22} and α^{33} are negative. This means that the marginal costs are decreasing in trolley-bus, motor-bus and tramway seat-kilometers. The first-order coefficients are the highest for tramway, followed by trolley-bus and motor-bus. As trolley-bus and tramway are network-related with high fixed costs in relation to variable costs the coefficients are reasonable. As it was said above our model is not linear homogeneous in input prices. The coefficients β^1 and β^2 are positive. As expected, the sign of the coefficient α_n is positive, showing that a higher number of stops and therefore a larger network increase costs. The negative coefficient α_t show that companies reduced average costs in the considered time period.

Table 2: Regression results from the model with factor prices

Parameter	Estimate	Parameter	Estimate
α_0	86053.36*** (2794.22)	α^{12}	0.01 (0.05)
α^1	88.92*** (8.75)	α^{13}	-0.01 (0.02)
α^2	71.32*** (6.94)	α^{23}	0.02* (0.01)
α^3	92.68*** (6.14)	β^1	0.09*** (0.04)
α^{11}	-0.02 (0.04)	β^2	5.79*** (1.07)
α^{22}	-0.02 (0.02)	α^n	56.40*** (13.23)
α^{33}	-0.03*** (0.01)	α^t	-372.00*** (118.64)

***, ** and * refer to 1%, 5% and 10% level of significance, respectively. Standard errors are in parenthesis.

The estimation results presented in Table 2 can be used to get some information on the economies of scale and scope.

Following Baumol, Panzar et al. (1982) global economies of scale¹⁰ in a multi-output setting are defined as:

$$SL = \frac{C(y)}{\sum_m^M y^{(m)} * \frac{\partial C}{\partial y^{(m)}}} \quad (\text{Equation 3})$$

where $y=(y^{(1)}, y^{(2)}, y^{(3)})$ for $m=1$ (trolley-bus), 2 (motor-bus) and 3 (tramway). Global economies of scale describe the cost behavior due to proportional changes in the entire production.

In addition, product-specific economies of scale relate to changes of at least one output, while at least another output is held constant. Product-specific economies of scale to the product m are defined as:

$$SL_m = \frac{C(y) - C(y^{(-m)})}{y^{(m)} * \frac{\partial C}{\partial y^{(m)}}} \quad (\text{Equation 4})$$

and

$$SL_{mn} = \frac{C(y) - C(y^{(-mn)})}{y^{(m)} * \frac{\partial C}{\partial y^{(m)}} + y^{(n)} * \frac{\partial C}{\partial y^{(n)}}} \quad (\text{Equation 5})$$

where $C(y) - C(y^{(-m)})$ represents the incremental cost relating to the m^{th} product; $C(y^{(-m)})$ is the costs of producing all the outputs jointly except output m . By the definitions above returns to scale are increasing, constant or decreasing if SL (or SL_m or SL_{mn}) is greater, equal or less than one.

Following Baumol, Panzar et al. (1982) economies of scope exist in the three output case if

$$C(y) < C(y^{(1)}, 0, 0) + C(0, y^{(2)}, 0) + C(0, 0, y^{(3)}). \quad (\text{Equation 6})$$

Economies of scope are present when there are cost efficiencies to be gained by joint production of multiple products. The degree of global economies of scope in the production of two products is defined as

$$SC = \frac{C(y^{(1)}, 0, 0) + C(0, y^{(2)}, 0) + C(0, 0, y^{(3)}) - C(y)}{C(y)}. \quad (\text{Equation 7})$$

¹⁰ In the definition of economies of scale we do not follow Caves, Christensen et al. (1984) by distinguishing between economies of scale and economies of density due to the complication of weighting the different network elements.

Global economies (diseconomies) of scope exist if $SC > 0$ (< 0).

In addition to the above measure, another measure can be defined for the case of more than two outputs. The degree of product-specific economies of scope SC_m measures the proportional increase in costs resulting from producing all of the outputs except the m^{th} one:

$$SC_m = \frac{C(y^{(m)}) + C(y^{(-m)}) - C(y)}{C(y)}. \quad (\text{Equation 8})$$

Following Fraquelli, Piacenza et al. (2004b) the degree of product-specific economies of scope for couples of outputs whereas the production of the remaining output is zero, is:

$$SC_{mn} = \frac{C(y^{(m)}) + C(y^{(n)}) - C(y^{(m)}, y^{(n)})}{C(y^{(m)}, y^{(n)})}. \quad (\text{Equation 9})$$

Product-specific economies (diseconomies) of scope exist if SC_m and SC_{mn} respectively is greater (smaller) than zero.

In order to study the variation of scale and scope economies in the sample, we considered several representative sample points regarding outputs. In particular, we estimated the scale economies respectively for output values at the sample mean, median, 1st and 3rd quartiles output values after excluding zero output values. For all non-output variables that enter in the equations, we considered the sample mean values. For instance, the median point consists of median values of all outputs except zero values with all other variables kept at the sample point.

Table 3 shows the point estimates with standard errors in parentheses. For all the computed output levels global increasing returns to scale exist and are significantly different from one. The estimates for product-specific returns to scale for tramways are also for all the computed output levels significantly different from one and indicate increasing returns, whereas the numbers of product-specific economies of scale for trolley-bus and motor-bus are not significant. Also product-specific returns to scale for two outputs (SL_{12} , SL_{13} and SL_{23}) exist. They are significantly different from one in the case of joint production of trolley-bus/tramway and motor-bus/ tramway for 1st and 3rd quartile output levels.

Table 3: Economies of scale estimates

Output	SL (global)	SL ₁ (trolley)	SL ₂ (motor-bus)	SL ₃ (tramway)	SL ₁₂ (trolley/ motor-bus)	SL ₁₃ (trolley/ tram)	SL ₂₃ (motor- bus/tram)
1st Quartile	1.17** (0.08)	1.01 (0.02)	1.02 (0.01)	1.04*** (0.01)	1.01 (0.03)	1.03** (0.02)	1.01* (0.01)
Median	1.11*** (0.04)	1.03 (0.05)	1.03 (0.03)	1.06*** (0.02)	1.01 (0.06)	1.06 (0.04)	1.02 (0.01)
Mean	1.08** (0.03)	1.03 (0.06)	1.05 (0.05)	1.06*** (0.02)	1.02 (0.08)	1.06 (0.04)	1.01 (0.02)
3rd Quartile	1.24*** (0.09)	1.05 (0.09)	1.04 (0.04)	1.43** (0.21)	1.02 (0.10)	1.36* (0.19)	1.23** (0.11)

***, ** and * refer to 1%, 5% and 10% level of significance, respectively. Standard errors are in parenthesis.

Table 4 shows the point estimates for economies of scope with standard errors in parentheses. Most of the numbers are larger than zero, indicating that mostly economies of scope do exist. For the global economies of scope this means that when producing median output levels total costs are 13 percent lower when offering all the three outputs by one company as if it was produced by specialized firms. In general economies of scope are decreasing with an increase in outputs. The computed values are statistically different from zero at the 1st quartile output and also for some median output levels. The product-specific economies of scope when one output is produced by a company and the other two by another company (SC₁, SC₂, SC₃) are at the 1st quartile output level in a similar range for all the three outputs (12 – 13%). The joint production of trolley-bus and tramway also yields economies of scope. Even higher are the cost savings from a couple production of trolley-bus und motor-bus (26% at the 1st quartile output).

Table 4: Economies of scope estimates

Output	SC (global)	SC ₁ (trolley)	SC ₂ (motor- bus)	SC ₃ (tram)	SC ₁₂ (trolley/ motor-bus)	SC ₁₃ (trolley/ tram)	SC ₂₃ (motor- bus/tram)
1. Quartile	0.26** (0.12)	0.13** (0.06)	0.12** (0.06)	0.13** (0.06)	0.26** (0.11)	0.16** (0.07)	0.15** (0.07)
Median	0.13* (0.07)	0.07* (0.04)	0.05 (0.04)	0.06 (0.05)	0.13* (0.07)	0.10* (0.06)	0.08 (0.05)
Mean	0.09 (0.06)	0.06 (0.04)	0.02 (0.05)	0.04 (0.04)	0.08 (0.08)	0.10 (0.06)	0.04 (0.05)
3. Quartile	0.01 (0.05)	0.04 (0.06)	-0.04 (0.05)	-0.01 (0.07)	0.06 (0.10)	0.06 (0.10)	-0.04 (0.04)

***, ** and * refer to 1%, 5% and 10% level of significance, respectively. Standard errors are in parenthesis.

As it has been shown by Kim and Clark (1988) and Fraquelli, Piacenza et al. (2004b), there is an interaction of scale and scope economies: The degree of global scale economies and scope economies depends positively on both product-specific scale economies and product-specific scope economies. This means that sufficiently strong economies of scale can imply an existence of economies of scope.

5. Discussion

The goal of this paper is to make a contribution to the ongoing discussion about tendering local transportation services. The empirical results have given insight into the cost structure of multi-mode public transport companies. They show that the local transportation sector is characterized by the existence of increasing returns to scale and by economies of scope. Therefore, an unbundling of a multi-output company into single-output companies leads to higher costs in the market as the synergies in the joint production are no longer exploited.

On the other hand the benefits from the introduction of a tendering procedure (competition for the market) are higher when this procedure is implemented for single lines as the barriers to entry are lower compared to a tendering procedure for a multi-mode network. Following Cambini and Filippini (2003) network tendering is more complex than line tendering and the number of potential bidders is lower. Therefore, the trade-off from unbundling between the loss of economies of scope and the gain of higher cost efficiency from the introduction of competition for the market exists.

An alternative to the introduction of competitive tendering procedures could be the introduction of incentive regulation instruments such as yardstick competition. The advantage of this regulatory instrument is to allow the exploitation of the economies of scale and scope to promote the cost efficiency by avoiding the implementation problems related to the introduction of competitive tendering policies for urban transit systems.

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