Regulating Public Transit Networks: How Do Urban-Intercity Diversification and Speed-up Measures Affect Firms' Cost Performance?

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Regulating Public Transit Networks: How Do Urban-Intercity Diversification and Speed-up Measures Affect Firms' Cost Performance? ♣

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Abstract

Empirical studies on the cost structure of Public Transit Networks are mainly based on specialized firms providing urban or intercity services. In this study we estimate a translogarithmic variable cost function to assess the behavior of returns to scale and the impact of network characteristics. The analysis is based on a sample of 45 Italian municipal companies observed from 1996 to 1998 and including both specialized and mixed transit operators. Results confirm previous evidence on the existence of natural monopoly in the industry and support a regulation introducing competitive tenders to access to the market. In addition, we provide insights about the advantages associated with urban-intercity diversification and with the improvement of network commercial speed. Cost benefits can then be achieved by promoting mergers between neighboring firms, so as to create new companies operating on an integrated local network and supplying in combination urban and intercity public transport. Implications of such a strategy for the design of tender mechanisms are also underlined, together with the need for a regulatory policy which takes more care of speed-up interventions.

Key words: urban and intercity public transport, cost structure, network characteristics, regulation

JEL: L5, L92, R41

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1. Introduction

In most of continental Europe, local public transportation (LPT) is a regulated activity. A local authority (Region or smaller local body) regulates each network whereas a single multi-modal company provides the transit service. The services operated by more than one firm are an exception. Public transit systems generally face universal service obligation and the demand for this service is promoted through low user charges and considerable subsidies.

At present, the high operating costs of the transit firms constitute a great challenge for political authorities, given the permanent deficit characterizing the sector. Traditionally, the empirical literature on the LPT networks has focused on the analysis of returns to scale to verify the presence of scale inefficiency. More recently, an increasing attention has been given to the incentives for the manager at pursuing the goal of x-efficiency, as a consequence of competitive tendering mechanisms (Dalen and Gomez-Lobo, 1996) and/or appropriate subsidy schemes (Gagnepain and Ivaldi, 2002). However, the impact of network characteristics on cost differences among companies and the relative policy interventions has never been stressed enough. The aim of this paper is just to show how the mobility organization and regulation can substantially improve firms' performances by acting on some structural and environmental factors which characterize the network where LPT companies operate.

The network configuration, i.e. urban or intercity area, could influence the cost of transit operations, given the differences in the management and the organization of two types of service. Within the framework of the Italian LPT industry, where many companies provide the service in both areas, it is interesting investigate possible cost advantages linked to the so-called 'mixed' activity, that is the urban-intercity diversification. This leads at reconsidering the traditional issue of scale economies, so as to take into account the eventual existence of productive synergies between urban and intercity service and the consequent cost benefits achievable by mergers of specialized firms. The analysis is particularly relevant in the light of the ongoing evolution in the Italian regulatory framework. The reform process started with Law 549/1995 includes among its goals the creation of a more competitive environment in the LPT supply, mainly by the resort to tendering mechanisms for the allotment of service concessions (Boitani and Cambini, 2002). The empirical evidence on the presence of both scale and scope economies, would provide some insights about the proper configuration of the network to be put in a tender.

A second important element affecting operating costs is represented by local traffic conditions and specific geographical and historical characteristics of served area, which turn out into different levels of network commercial speed. If the latter are almost exogenous with respect to transit firm's activity, they are not at the level of network regulation. Several speed-up measures can be implemented by local authorities in order to reduce traffic congestion and improve environmental conditions for LPT vehicles (FitzRoy and Smith, 1994), with positive effects on the operating costs level.

The study uses a sample of 45 Italian LPT firms providing urban, intercity, or mixed service in the period from 1996 to 1998. The analysis is carried out through the econometric estimation of a variable cost function. We adopt the flexible translogaritmic specification, which allows us to assess the behavior of returns to scale and the effects on costs of environmental factors at different sample points. Network characteristics are considered in the model by introducing the average commercial speed of LPT vehicles and service-specific dummies for intercity and mixed activities.

The remainder of the paper is organized as follows. After a concise description of the Italian LPT sector (Section 2), in Section 3 we briefly review main findings of the empirical literature. Section 4 presents the econometric cost model, i.e. the included explanatory variables, the functional form, and the estimation method. Section 5 describes the database, paying attention to the construction and the features of each variable. Section 6 comments on the empirical results, while conclusion and policy suggestions complete the work (Section 7).

2. Characteristics of public transit in Italy

The Italian LPT sector includes urban and intercity transportation systems. One can find several examples of multi-product firms providing in combination urban and intercity service. The different transit modes include:

- bus-lines, operating in both the urban and the intercity areas;
- tramways, that provide urban service in five cities (Turin, Milan, Trieste, Rome, and Naples) and intercity service only in Milan;
- subways, with urban service in Rome, Milan and Naples;
- private railways, operating on an intercity scale;
- regional railways coming from the recent breakup of local rail-lines from the State Railways (FS) company.

As in the majority of European countries, the road-mode of transportation in Italy has been progressively increasing in importance and at present the supply of bus services dominates the sector. Bus-lines system embraces more than 1,100 firms, 18 per cent of which provide only urban services, 67 per cent only intercity services, and the remaining 15 per cent supply both types of service (Ministry of Transports and Navigation, 1997).

As to the ownership structure of supplying companies, it is worthwhile to note the predominant position of public companies.[1] Traffic data (number of buses, service workers and passengers) during the years 1985-1995 certainly highlights a progressive relevance of the private sector. Nevertheless, the weight of the local public-owned companies continues to be decisive, especially in terms of the number of passengers (85 percent public versus 15 percent private in 1995).

When compared to European standards, Italian transit companies reveal worse results with respect to cost and productivity levels. Table 1 (ISOTOPE Project of the European Commission, 1998), shows the main efficiency indicators for Italy, "Other European Countries", and United Kingdom. In terms of labor productivity, the Italian sector shows a lower performance (14.77 vehicle-kms per service worker) than the other European regions (19.38 for the "Other European Countries" and 20.39 for the United Kingdom). The data concerning the operating costs per vehicle-km (3.02 ECU against 2.16 for the "Other European Countries" and 1.44 for the United Kingdom) points to similar problems. Moreover, a recent study carried out by CNR (1999) underlines that, in the period from 1992 to 1997, the gap between costs and proceeds grew by further 13 percentage points, in spite of the positive dynamics of the tariffs level.

[1] In some European countries, private ownership dominates the public sector. The French case is emblematic, where public firms fall short of 35 per cent.

3. Literature review

3.1. International findings

The international empirical studies of LPT technology are mainly based on samples of specialised companies providing either urban or intercity service. The few contributions concerning multi-product (intercity and urban) activities do not investigate the possible advantages associated with the diversification of the service. The study of *output cost elasticity* and of *substitution elasticity between factors* are the main topics of the analysis.[2]

The evidence on returns to scale can be summarized as follows:[3]

- almost all the studies confirm the presence of *short-run economies of size*.[4] This seems to reveal the existence of unused capacity. Two circumstances are relevant for the economy of the transportation companies: the massive public contribution to the capital investments and the importance of the so-called *peak-load problem*. Indeed, the capacity necessary to satisfy the peak demand unavoidably creates unused capacity in the low demand phases.
- the evidence of *long-run economies of size* is uncertain. It seems that the nature of the sample and the way of computing the capital price are crucial elements in orienting the results. In particular, in the studies on the intercity transport

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[2] The analysis of the production and cost structure of a particular industry often concentrates on the degree of *returns to scale*. It summarizes how fast costs rise with respect to output(s). If output y is a scalar, returns to scale are simply defined as the inverse of the output cost elasticity:

$$s = \frac{AC}{MC} = \frac{C}{y.(\partial C / \partial y)}$$

If marginal costs ($MC = \partial C/\partial y$) are less than average costs ($AC = C/y$), so that $s > 1$ (equivalently, if AC is falling in y), we have *increasing returns*, also called *economies of scale*. The opposite case ($s < 1$) is denoted *decreasing returns* or *diseconomies of scale*; and $s = 1$ defines *constant returns*. In the specific context of the transportation industry it is possible to make a distinction between expanding the *density* of output, for example by adding more vehicles or attracting more passengers on a given route, and expanding the *spatial scale* of output, for example by adding new routes with similar densities. The former often allows a more intense use of the equipment, thereby lowering average cost. This form of increasing returns to scale is usually called *increasing returns to density* or *economies of density*, to distinguish it from the degree of returns to scale that characterizes an expansion of the entire productive dimension, denoted *increasing returns to size* or *economies of size*. For more details on these aspects, see Braeutigam (1999).

[3] On this point, see also Fabbri (1998).

[4] See, among the others, Viton (1981), De Borger (1984), Obeng (1984), Thiry and Lawarree (1987), Caves and Christensen (1988), Gagnepain (1998), Matas and Raymond (1998). As an example of study that found diseconomies in the short-run, refer to Dalen and Gomez-Lobo (1996).

systems the presence of remarkable economies of size is found. The latter decrease with increasing firm scale;[5]

- the existence of *economies of network density* is confirmed by many works.[6] The average costs are decreasing at the growing of the output, given the network size;
- the sector benefits of significant *economies of use intensity*.[7] This fact reveals the existence of excess capacity regarding the intermediate output (potential for trips, e.g. seat-kilometers).

As regards the analysis of the substitutability between productive factors (usually identified with fuel, labor, capital and maintenance), it emerges a quasi-fixed coefficients technology, given the small values typically found for the substitution elasticity. However, substitutability between capital and maintenance appears to be relatively more marked than in the cases of labor and capital or labor and fuel. On the basis of these findings, one can infer that the demand for productive factors is substantially inelastic to own price and presents very low values for the cross-elasticity.

3.2. Italian findings

As far as Italian studies are concerned, the few articles published in recent years are summarized in Table 2, with their main characteristics and results.

All listed contributions adopt the flexible translog cost function and focus on the bus service.[8] Only one of these studies (Fazioli, Filippini and Prioni, 1993) chose to analyze the productive structure in terms of total costs, while the other two (Fabbri, 1998 and Levaggi, 1994) considered a variable cost function model

[5] To this regard, see De Borger (1984), Berechman (1987), Filippini, Maggi and Prioni (1992). As far as urban transport is concerned, the presence of significant economies of scale was found in the studies carried out by Thiry and Lawarree (1987), Andrikopoulos, Loizidis and Prodromidis (1992), Gagnepain and Ivaldi (2002).

[6] Among the others, refer to Windle (1988), Filippini, Maggi and Prioni (1992), Matas and Raymond (1998), Gagnepain (1998).

[7] This is another concept of density economies which is very recurrent in the transportation literature that uses a final-output-oriented specification of the production function (e.g. passenger-kilometers). It indicates the reduction of unitary per passenger cost due to the increase of served users on a transit system with given capacity. Some examples in literature are found in the works of Berechman (1983), Button and O'Donnel (1985), Caves and Christensen (1988), Windle (1988).

[8] It is wortwhile to underline that this transit mode accounts for over 80 per cent of LPT services in terms of supplied seat-kilometers. To this regard see also Section 2.

more appropriate. The strict dependence on the government grants-in-aid program suggested to treat the capital stock as fixed in the short run.

Fazioli et al. and Levaggi focused only on the intercity and urban transport respectively; Fabbri analyzed both compartments. Levaggi works on a sample of companies operating throughout Italy, while Fabbri and Fazioli et al. concentrate only on a region of North-Italy (Emilia Romagna). The three studies differ also in the measure of the output: vehicle-kilometers and seat-kilometers (both supply-oriented measures) in Fabbri and Fazioli et al. respectively, passenger-kilometers (demand-oriented measure) in Levaggi.

We will just list the main findings:

- both studies using a variable cost model reveal the existence of *short-run economies of size*;
- as regards *long-run economies of size*, the evidence is uncertain. The results seem crucially depend on the index used to represent the output. In particular, the studies using intermediate (or supply-oriented) measures of output reveal the existence of significant economies of size;
- the analysis of *network density economies* too leads to inconclusive outcomes. While in Fazioli et al. remarkable increasing returns to network density are observed at all data point, Levaggi found evidence of positive returns only in the short run;
- finally, Levaggi gives evidence of a very high degree of *economies of use intensity*, both in the short and the long run.

4. The econometric cost function model

Our empirical analysis is based on a variable cost function model. The fixed assets investments in the Italian LPT sector are strictly related to government subsidy programs, so it is not appropriate to suppose that firms exhibit a cost-minimizing behavior with respect to capital too. Thus, as Windle (1988), Levaggi (1994) and Fabbri (1998) suggest, the capital stock should be considered as a fixed factor in the short-run.

The cost function includes one output and three variable inputs: labor (L), fuel (F), materials and services (MS). Since network characteristics are expected to have a significant impact on the operating costs level, we add two *service-specific dummies* for intercity and mixed firms. In such a way, we can take into account cost differences due to the management and organization of different network configurations. We are particularly interested at verifying the presence of any advantage from urban-intercity diversification (mixed activity). To the best of our knowledge, this is the first attempt in the empirical literature on LPT systems to investigate these aspects. The issue takes cue from preliminary evidence emerged in Fraquelli et al. (2001), where some insights into the cost savings associated with the provision of a mixed service have been advanced.

The environmental characteristics of the territorial area where the service is provided makes it difficult to compare the cost performance of different operators. Indeed, local traffic conditions and geographical and historical factors are peculiar to each public transit system and influence the structure and the operability of its network. To some extent, the *average commercial speed* of LPT vehicles reflect these differences, so we decided to incorporate it into the cost function model. Network speed represents a typical indicator of quality of the transit service, since it provides an information about the duration of a journey between a departure point and an arrival point. This variable simultaneously affects the user demand and the supply of public transport (Gagnepain, 1998). On the one hand, the transfer time represents an important criterion for people to choose among alternative transit modes, as they will prefer to use private car or taxi if these allow them to move more rapidly. A rise of the LPT demand may therefore be achieved by improving the commercial speed of the network. On the other hand, if a given trip is covered in a shorter time, then a lesser amount of rolling stock and working hours is likely to be required for providing the service. As a consequence, operating costs are expected to lower with increasing network speed.[9]

We adopt a translog specification of the cost function (Christensen and Greene, 1976). Given the regularity conditions ensuring duality, the translog functional form does not impose any other a priori restriction on the characteristics of the underlying technology.[10] In particular, the estimated elasticities of substitution

[9] See Gagnepain (1998), page 98.

[10] To be consistent with cost minimization, [1] must satisfy symmetry ($\beta_{ij} = \beta_{ji}$ for all couples i, j) as well as the following properties: *a*) non-negative fitted costs; *b*) non-negative fitted marginal costs with respect to output; *c*) homogeneity of degree one of the cost function in input prices ($\Sigma_i\beta_i$

between factors and the degree of returns to scale are allowed to vary throughout the sample according to the output level, input prices, capital stock, and network speed. The translog variable cost function is defined by the following equation:

$$\begin{aligned}\ln VC = & \beta_0 + \beta_y \ln Y + \beta_k \ln K + \sum_i \beta_i \ln P_i + \beta_{SP} \ln SP + \sum_i \beta_{iy} \ln P_i \ln Y \\ & + \sum_i \beta_{ik} \ln P_i \ln K + \sum_i \beta_{iSP} \ln P_i \ln SP + \beta_{yk} \ln Y \ln K \\ & + \beta_{ySP} \ln Y \ln SP + \beta_{kSP} \ln K \ln SP + \frac{1}{2}\beta_{yy} (\ln Y)^2 \\ & + \frac{1}{2}\beta_{kk} (\ln K)^2 + \frac{1}{2}\beta_{SPSP} (\ln SP)^2 + \frac{1}{2}\sum_i \sum_j \beta_{ij} \ln P_i \ln P_j \\ & + DINTC + DMIX + \psi_{VC} \\ & i,j \in \{L, MS, F\}\end{aligned} \qquad [1]$$

where VC indicates variable operating costs, Y the output level, K the capital stock (quasi-fixed input), P_i the price of productive factor i, SP the average commercial speed of the network, *DINT* and *DMIX* are dummy variables for the intercity and mixed service respectively, and ψ_{VC} is a random noise reflecting the stochastic structure of the cost function. Definitions and measurement procedures of these variables are discussed in detail in the next section.

Although model [1] is a flexible form in the sense specified by Diewert (1974), however, because of the high number of parameters to be estimated, it can rise serious problems of statistical efficiency, in addition to the well-known issue of near multicollinearity among some regressors (Berndt, 1991). A typical solution to the efficiency problem consists in increasing the degrees of freedom, by jointly estimating via the Zellner's iterated seemingly unrelated regression (SUR) method the cost function and the related *factor cost-share equations* (Zellner, 1962). The latter can be derived applying the *Shephard's lemma* to expression [1]:

$$\frac{\partial \ln VC}{\partial \ln P_i} = \frac{\partial VC}{\partial P_i}\frac{P_i}{VC} = \frac{P_i x_i^D}{VC} = S_i \qquad i \in \{L, MS, F\} \qquad [2]$$

= 1 and $\Sigma_j\beta_{ij} = 0$ for all i, $\Sigma_i\beta_{iy} = 0$, $\Sigma_i\beta_{ik} = 0$, $\Sigma_i\beta_{iSP} = 0$); *d*) non-decreasing fitted costs in input prices; *e*) concavity of the cost function in input prices. Symmetry and linear homogeneity in input prices are imposed *a priori* during estimation, whilst the other regularity conditions are checked ex-post.

where x_i^D is the optimal demand for the *i*th input and S_i is the related share with respect to the variable cost. Since the factor cost-shares add up to one ("adding-up" condition), we would have a system with an equation linearly depending on the others. To solve the singularity problem of the variance-covariance matrix of the disturbance terms, we have to drop an arbitrary equation (in this case S_{MS}) and estimate the remaining factor share equations by the SUR procedure.[11] Applying [2] to [1], we obtain the following equations to estimate jointly with [1]:

$$S_i = \beta_i + \beta_{iy} \ln Y + \beta_{ik} \ln K + \sum_j \beta_{ij} \ln P_j + \beta_{iSP} \ln SP + \psi_i \qquad [3]$$

$$i \in \{L, F\} \quad ; \quad j \in \{L, MS, F\}$$

where ψ_i is a random noise reflecting the stochastic structure of the *i*th factor cost-share.[12]

5. Data and variables description

The dataset refers to a balanced panel of 45 municipal public transit companies associated to Federtrasporti[13] operating over the period 1996-1998, for a total of 135 *pooled* observations.[14] The sample has the peculiarity of including both specialized and multi-product LPT operators: 18 firms mainly serve urban areas, 15 provide intercity service for the most part, and the remaining 12 are so-called mixed companies which have activities in the two sectors.[15] Service-specific dummy *DINTC* in the cost function assume value 1 for intercity companies and 0

[11] Parameter estimates are invariant with respect to the choice of deleted equation as long as the *Iterated SUR* (or *Maximum Likelihood*) estimation technique is employed on the $M - 1$ factor share equations. See Berndt (1991) for more details on this topic.
[12] The software used for the estimation is the SUREG command of STATA Version 6.
[13] Federtrasporti (Rome) is a nationwide trade organization which associates publicly-owned LPT companies in Italy. In 2001 it merged with FENIT, a nationwide trade organization which includes railway systems different from FS and privately-owned bus operators, and assumed the new name ASSTRA.
[14] Since we were working on a panel data in which each firm is observed over a period of three years, we had to choose whether to add to the model a fixed effect for every year or eventually a time-trend variable. To tackle this issue we performed Wald tests after having included in the model two time dummies for 1996 and 1998 or a time-trend. At the usual confidence levels, both the null hypothesis of constancy of the intercept over time and the null hypothesis of not significant time-trend effect could not be rejected. Thus we opted for a simple regression based on the pooled observations.
[15] Data mainly refers to bus transit mode. Only 8 companies in the sample provide a multi-modal service including also tramways, trolley-lines, and railways.

otherwise, similarly *DMIX* is equal to 1 in the case of mixed operators and 0 for specialized networks. So, we have the possibility to test the existence of different cost levels for urban and intercity services and of eventual savings associated with the multi-product activity. As for firm size, measured in terms of average number of employed workers in 1998, the sample includes 12 large-sized companies (more than 550 workers), 22 medium-sized units (200-550 workers), and 11 small operators (less than 200 workers).

Data about costs, output quantities, capital stock, input prices and network characteristics have been collected by integrating the information available in the annual reports of Federtrasporti (1998, 1999, 2000) with additional information drawn from questionnaires sent to firms' managers. Variable operating cost (*VC*) is the sum of labor, fuel, and materials and services expenses.

We adopt a measure of output (*Y*) recently proposed by Gagnepain and Ivaldi (2002) to study the cost structure of the French LPT systems. Output is computed as the number of total places offered times the number of total traveled kilometers in each year.[16] Compared to supply-oriented indicators usually employed in the transportation literature (vehicle-kilometers or seat-kilometers), this definition is innovative. Even if it does not allow us to separate the effects on costs of pure size economies from network density economies (see Section 3), it has the worth to reflect in a single measure the global productive structure of the firm. Indeed, this indicator takes simultaneously into account the length of the network, the frequency of the service and the size of the fleet.[17] On the other hand, the resort to a single output specification of the cost function, without including the extent of the network as a second output indicator, is expected to reduce the problems of multicollinearity among physical variables (outputs, fixed inputs, environmental factors) which have been often emphasized by the empirical literature on network industries. Furthermore, the use of a composite measure is particularly suitable to model the output for our sample firms, since it allows to weight the specific characteristics of urban and intercity activities.[18]

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[16] Total places offered by each company were calculated by multiplying the number of buses in circulation by their average load capacity.

[17] As Gagnepain and Ivaldi (2002) underline, the network capacity is also a measure of the quality of service.

[18] In general, intercity operators cover a larger network and they can potentially perform a higher number of kilometers than urban companies, but the operative context is very different (a lower

Capital (K) plays the role of fixed input in our short-run cost model. For each company it has been calculated as the number of vehicles in the rolling stock weighted by the relative average fleet age.[19] The age of the fleet is likely to influence the quantities required of variable inputs (i.e. labor, fuel, materials and services) to provide a certain amount of transit service. Therefore, we decided for a weighted measure. The latter allows us to control for wear differences of rolling stocks and consequent effects on operating costs, especially from the side of maintenance expenses which are typically linked to the age of vehicles.

The price of labor (P_L) is given by the ratio of total salary expenses to the average number of employees (drivers, maintenance workers and administrative staff). Fuel price (P_F) has been obtained by dividing fuel costs by liters of diesel oil consumed.[20] Expenses for materials and services represent a residual cost category. They have been divided by the number of seat-kilometers offered[21] to obtain an average price for this input (P_{MS}), since it is reasonable to assume that this kind of expenses strictly depends on the actual exploitation of the network.

In addition to the standard variables of a proper cost function, we included in the model the average commercial speed (SP). This variable, already considered in previous studies on the cost structure of LPT systems (Windle, 1988; Levaggi, 1994; Wunsch, 1996; Gagnepain, 1998), permits to control for the heterogeneity in traffic conditions and the environmental characteristics of each network. We think this aspect is particularly relevant when considering both urban and intercity services. Average network speed is given by the ratio of total traveled kilometers to the number of total working hours on line of drivers, thus, it is defined in terms of kilometers per hour (kms/h).

Table 3 provides summary statistics (mean, variability index, minimum, and maximum) for all the variables included in the translog system [1]-[3]. Data are

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number of passengers, longer trips, different traffic conditions). On the other hand, urban firms usually offer a more frequent service and a higher number of places (buses are larger due to the more intensive demand to be satisfied).

[19] Capital measure is defined by: $K_i = (number\ of\ vehicles) * \left(\frac{age_c}{age_i} \right)$ where age_c is the average fleet age in the whole sample, while age_i is the average fleet age of the i-th firm.

[20] For a few firms utilizing tramways, trolley-lines or railways and consuming electricity, kilowatt-hours were transformed in "equivalent" liters of diesel oil.

[21] Annual seat-kilometers are the multiplication of traveled kilometers by the average load capacity of vehicles in circulation.

reported both for the overall sample and by type of service provided, i.e. urban, intercity, or mixed. We can note a great variability within each column, especially in the values of costs, output and capital stock. As for the comparison among the three types of networks, it is worthwhile to highlight the remarkable differences in the average commercial speed level (urban, 16.45 kms/h; mixed, 25.23 kms/h; intercity, 29.44 kms/h), whilst the mean values of factor prices and relative cost-shares are almost invariant.

6. Empirical results

Table 4 presents the results of the joint estimation of the translog variable cost function and relative factor share equations for labor and fuel. On the whole, the model fits the data very well. The R^2 value for the cost function indicates that 98.6 percent of the variance in the dependent variable is explained by the variance in the regressors. The p-value associated with the F statistic confirms the general goodness of fit. It is worthwhile to notice that input cost-shares estimates for the average firm of the sample (i.e. parameters β_L, β_{MS} and β_F) are quite similar to their sample mean values reported in Table 3.[22] The estimated cost function also satisfies *each* of the regularity conditions required by the duality theory (see footnote 11) at 83 percent of the sample data points.[23]

The estimated parameters are almost all statistically significant at least at the 5% level[24] and their sign is consistent with the expectations. The only exception concerns the positive first-order coefficient associated with the fixed input, β_k. The evidence that the variable costs increase with larger rolling stocks is not

[22] The *average firm* is an hypothetical productive unit exhibiting sample average values for each variable included in the cost model, that is output level, stock of fixed input, factor prices, and network commercial speed. Since all the independent variables was normalized on their respective sample mean before the transformation in logarithms, parameters associated with the first-order price terms return a direct estimate of corresponding input cost-shares for the average firm.

[23] More precisely, fitted *VC* is always non-negative, non-decreasing in output (positive marginal costs), and non-decreasing in input prices (fitted factor shares are positive at each observation). The condition of concavity of the cost function in input prices (hessian matrix based on the fitted factor shares must be negative semi-definite) is satisfied for 112 observations on 135.

[24] Only the coefficients associated with the quadratic terms for Y and K (β_{yy} and β_{kk}) and with the interaction between Y and K (β_{yk}) are significant at the 10% level. As for the interaction of P_F with Y and K, instead, the null hypothesis of zero value for the relative parameters cannot be rejected at the 10% level of significance.

consistent with the microeconomic theory.[25] With regards to this problem, an intense debate arose in the literature. According to Filippini (1996), the positive sign of β_k is due to a problem of multicollinearity in cases where there exists a positive correlation between the dependent variable and the capital measure. The alternative argument suggested by Caves et al. (1985) and Windle (1988) is that the positive sign of β_k reflects an industry which does not minimize costs in the long term and therefore employs too much capital in the production process. This could be indeed the situation characterizing the Italian LPT sector. As Levaggi (1994) argues, the inefficient use of capital is likely to derive from the generous government programs of subsiding investments.

In the rest of this section one will take a look at the standard technological properties (scale economies and input substitutability) evaluated at the sample mean (Table 5). We postpone to Section 6.1 the discussion concerning the effects on costs of network characteristics (type of service and commercial speed), which are the primary interest of this study.

Given the normalization of the data, estimated first-order coefficients can be usefully interpreted as cost elasticities for the average LPT operator. Parameter β_y indicates that a 10 percent increase of output rises operating costs by about 4.5 percent. The reciprocal of output cost elasticity (ε_y) gives the estimate of *short-run returns to scale* (*SRS*):

$$SRS = \frac{1}{\varepsilon_y} = 2.21 \qquad [4]$$

We can also evaluate the *long-run returns to scale* (*LRS*) by applying the following algorithm, firstly suggested by Caves et al. (1981):

$$LRS = \frac{1-\varepsilon_k}{\varepsilon_y} = 1.84 \qquad [5]$$

where ε_k is the cost elasticity with respect to capital (here β_k). It is worthwhile to remark that we use a composite output. As the effects on costs due to an increase in the number of places offered, the network length or the service frequency are

[25] This seems to be a general problem that characterizes the use of a variable cost model, not only in the transportation industry. For a discussion on these issues see also Fabbri (1998).

not distinguishable, returns to scale incorporate both size and network density economies.

T-tests lead to accept the hypothesis of values significantly larger than one for both *SRS* and *LRS*.[26] The implied short-run scale economies indicate that, given the stock of fixed input, a proportional increase in the use of all variable factors produce a more than proportional growth of the output. This means that Italian companies are not fully exploiting their capital endowment, viz. the fleet owned by the operators would enable them to offer a greater service. Long-run scale economies point out that when the firm is allowed to optimize the use of all factors (included capital), its average unitary cost of production decreases with the output level. This result is consistent with some findings reviewed in Section 3.2 (Fazioli et al., 1993; Fabbri, 1998) and provides further insights about the feature of local natural monopoly of the Italian LPT sector.[27]

The translog specification allowed us also to estimates the values of *SRS* and *LRS* taking into account the firm size (small, medium, large) and the type of service (urban, intercity, mixed).[28] The variability registered in both short-run and long-run returns to scale is very low: increasing *SRS* and *LRS* were observed everywhere, regardless of the size and the configuration of the network, with *SRS* ranging from 1.91 (medium intercity firm) to 2.24 (small mixed firm), and *LRS* ranging from 1.80 (small mixed firm) to 1.90 (large intercity firm). This evidence validates our analysis of the industry in terms of average firm.

To analyze factor substitutability we started from the estimates of *Allen* partial elasticities of substitution and derived *Morishima* elasticities (Blackorby and Russell, 1989):

$$\sigma_{ij}^{M} = S_j(\sigma_{ij}^{A} - \sigma_{jj}^{A}) \quad i, j \in \{L, MS, F\} \qquad [6]$$

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[26] Test statistics are equal to 11.63 and 46.08, respectively.

[27] According to the economic theory the presence of scale economies in single-output technologies is a sufficient condition to have sub-additivity of the cost function and to establish the existence of natural monopoly in the industry (Panzar, 1989).

[28] For each combination of firm size and network configuration we calculated a mean value for output, capital, and commercial speed, using all the observations in the sub-sample except minute and giant units. This allowed us to define 9 different typologies of companies, according to the size and the type of service. Since network speed showed a low variability across firm sizes, we decided to let vary its mean value across types of service only. *SRS* and *LRS* were then estimated at the different combinations of firm size and network configuration, using the computed class values for output, capital, and commercial speed, with input prices fixed at their sample means.

where S_j is the estimated cost-share for input j, while $\sigma_{ij}{}^{A}$ and $\sigma_{jj}{}^{A}$ are the cross-Allen and own-Allen elasticities, respectively.[29] Morishima measures are more informative than the Allen ones, as they permits asymmetry in elasticities.[30]

The estimates reported in the fourth row of Table 5 are all quite low and less than one, so we can state that LPT technology allows a poor opportunity of substitution between productive factors. Substitution between labor and fuel is possible where an increase in the commercial speed reduces driving-hours with a simultaneous increase in fuel consumption. Furthermore, fuel consumption can be improved by a more intensive maintenance activity. Labor can be substitute of the composite input *MS* mainly in relation to the maintenance service. Indeed, the latter can be done inside the firm or assigned to an external company. On the other hand, as for the administrative staff, a more capital-intensive management system will require a lower number of workers. Finally, substitution between fuel and *MS* is possible when we think about materials for vehicles maintenance: a greater care of vehicles efficiency is likely to reduce fuel consumption.

The Allen elasticities can also be used to calculate the own-price elasticities of the derived demand for inputs.[31] Last row of Table 5 highlights fairly sticky factor demands, in particular for labor. In the Italian context, this could be due to the collective wage negotiation and the strong influence of trade unions, which make the labor market in the LPT sector particularly rigid.

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[29] From Berndt and Wood (1975):

$$\sigma_{ij}{}^{A} = \frac{\beta_{ij} + S_i S_j}{S_i S_j} \qquad i,j \in \{L, MS, F\}\ ;\ i \neq j$$

$$\sigma_{jj}{}^{A} = \frac{\beta_{jj} + S_j^2 - S_j}{S_j^2} \qquad j \in \{L, MS, F\}$$

where S_i and S_j are the estimated cost-shares for inputs i and j, while β_{ij} and β_{jj} are the estimated parameters for the second-order terms relative to input prices interaction.

[30] Morishima elasticity measures the curvature of the isoquant when adjustments are made in inputs i and j in response to a change in the price ratio P_i/P_j due to an increase in the price P_i. This will generally be different from the curvature moving in the other direction, when changes in P_i/P_j are due to an increase in P_j. See Seldon, Jewell and O'Brien (2000) for a recent application to the media substitutability in the advertising industry.

[31] They are obtained by the following formula from Berndt and Wood (1975): $\eta_{iPi} = S_i \sigma_{ii}{}^{A}$; $i \in \{L, MS, F\}$.

6.3. Effects of network characteristics

The peculiarity of our sample is to include LPT companies with different network configurations, i.e. providing urban, intercity, or both types of service. Third row of Table 5 reports the estimates of service-specific cost elasticities associated with the dummies for the intercity (*DINTC*) and mixed (*DMIX*) activity. Following Halvorsen and Palmquist (1980), these values are computed as $[\exp(DINTC) - 1]$ and $[\exp(DMIX) - 1]$, and they represent the percentage effect on variable costs due to the shift of firm's production from urban to intercity and mixed services, respectively.

Both elasticities have a negative sign and are statistically significant at the 1% level. First value, -0.11, means that a company operating in the intercity sector would suffer lower costs than a urban firm, other things being equal. This result is probably due to different environmental operating conditions (such as traffic congestion) and reflects a lesser difficulty in managing intercity LPT networks. Estimated cost elasticity for the mixed service, -0.14, provides more stimulating insights. Indeed, our findings indicate a lower operating cost for mixed networks not only with respect to urban firms, but also compared with the intercity ones.[32] This suggests that mixed public transit utilities are likely to enjoy cost savings from diversification of the service (*scope economies*). The benefits associated with the combined provision of urban and intercity services could arise from the better saturation of sharable inputs such as, in particular, the workforce (drivers and administrative staff) and, probably in a lesser extent, the rolling stock. These aspects are well emphasized in Table 6, which presents estimated average variable costs by type of service and firm size. One can firstly note the progressive reduction of average unitary costs of production from small to large sizes, consistently with the widespread presence of scale economies pointed out above. At the same time, for each class of firm size the unitary operating cost level of mixed companies is always lower than the one reported for specialized operators, with figures nearly halved compared to urban firms.

[32] The differential impact on variable costs due to the shift of firm's production from intercity to mixed services can be calculated as $[\exp(DMIX - DINTC) - 1]$ and it is equal to -0.03 (statistically significant at the 5% level).

It is worthwhile to interpret the results on the combined presence of scale economies and cost benefits from service diversification in the light of previous evidence emerged in Fazioli, Filippini and Prioni (1993). In that paper, the authors analyzed intercity public transport in a region of Italy (Emilia Romagna) and proposed mergers between companies operating in contiguous areas, so as to exploit returns to scale. Our findings suggest to extend this policy in a peculiar way. Our sample consists of firms providing urban, intercity and mixed services. In such a context, a merger between neighboring companies does not simply wide the productive scale, but probably also involves a change in the network configuration. This is rather obvious when we consider a merger between urban and intercity operators, leading to a single mixed firm. It makes sense also in the case of mergers between two urban companies, since it could be more efficient to enlarge the network so as to include also the intercity service linking the two cities (i.e. a mixed-activity firm again).

As for the impact of the average network speed, our findings confirm that it significantly affects firms' cost performance. Cost elasticity (ε_{SP}) for the average firm (second row of Table 5) indicates that increasing speed of LPT vehicles by 10 percent, for instance from 25 to 27.5 kms/h, can reduce variable costs by about 1.3 percent. Estimates of ε_{SP} for different classes of firm size and type of service highlight the presence of this effect throughout the industry, with low variability across sizes and a harder cost reaction for intercity and mixed companies.[33]

Speed-up measures can be implemented by re-allocating the existing road space away from private vehicles towards public passenger transport (reserved lanes for buses, restrictions on parking and traffic of cars and taxis) and providing incentives for the use of public modes (good intra- and inter-modal timetable coordination, introduction of multi-modal travelcards). As Gagnepain (1998) remarks, this calls out for suitable public policies concerning local traffic regulation. Indeed, the above interventions are not under the direct control of LPT operators but strictly rely on local authorities in charge of the territory management. The latter have a twofold interest in improving average network

[33] Estimates of ε_{SP} are -0.28 and -0.23 for medium-sized intercity and mixed firms, respectively, compared to -0.09 for a medium-sized urban operator. The lower cost reduction is probably due to

speed, as they would enjoy positive effects on both the public transit demand and the firms' costs level, besides the expected benefits in terms of lower environmental pollution. Their incentives to make the mobility for LPT vehicles more flowing will depend on the trade-off between the greater costs linked to the management of new infrastructures and the possible reduction of operating costs.

7. Conclusions and policy implications

The econometric estimation of a variable cost function for the Italian public transit systems highlight the presence of significant scale economies throughout the industry. Different firm sizes (small, medium, large) and types of service provided (urban, intercity, mixed) are all involved. This implies that LPT companies could gain advantage in terms of unitary operating costs by expanding their productive scale.

The findings support a policy of mergers among firms. We realize that this strategy may not be easy to implement, given the close connection between the public transit service and the specific environmental constraints that companies face in a local context. However, the results on scope economies associated with urban-intercity diversification provide further insights into this issue. We found that a mixed operator has lower costs compared with both urban and intercity specialized firms. Therefore, it could be desirable to encourage mergers between productive units providing the service in neighboring areas, so as to create companies operating on an integrated local network and supplying both urban and intercity public transport. This strategy might be particularly suitable for the Italian LPT industry, given the high-density distribution of urban centers throughout the country.

The presence of persistent scale economies also confirms the feature of local natural monopoly of the LPT sector. This would call for a corrective regulatory policy to achieve an acceptable outcome in terms of social welfare (Braeutigam, 1989). A good indirect intervention could be the redesign of the conditions of accessibility to the network by promoting forms of "competition-for-the-market"

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the higher traffic congestion characterizing urban contexts that damps down the potential benefits of network speed improvements.

(e.g. competitive auction to award the single license). The ongoing LPT reform in Italy is actually oriented towards this direction. Our findings on scale economies and cost benefits from the urban-intercity diversification have many implications about the configuration of the network that should be put in a competitive tender. As for the network size, they indicate that a greater network is better in terms of scale efficiency. However, the regulator must compare this advantage with the risk of reduction of effectiveness of the competitive mechanism. Indeed, given the financial constraints, smaller networks are likely to attract a higher number of operators competing for them, and this creates greater incentives to pursue the goal of x-efficiency. There is then a trade-off between the benefits from more competition and the advantages from scale efficiency. On the other hand, there is not any a priori motivation to think the number of competing firms to be conditioned by the type of service. If so, the creation of mixed networks to be put in tendering should be widely supported.

Public regulators must also define policies for local mobility. To this end, they dispose of many instruments, such as, inter-modality development, reserved lanes for buses, road pricing, focusing public opinion on environmental problems. The traffic regulation plays an important role on the productive structure of LPT service. Indeed, measures to increase network speed can significantly improve the cost performance of public transit systems. Our analysis confirms the positive impact of a more flowing mobility for LPT vehicles and suggests that in future greater interest with regards to speed-up interventions must be taken.

Table 1. Efficiency indicators for the urban bus service in Europe (yearly values)

Country	*Vehicle-kms* (*thousands*) */service worker*	*Operating costs* (*Ecu*) */vehicle-km*
Italy	14.77	3.02
"Other European Countries" (France, Denmark, Finland, Sweden)	19.38	2.16
United Kingdom	20.39	1.44

Source: European Commission (1998)

Table 2. Econometric cost studies on the Italian LPT sector

Authors	*Type of Model*	*LPT sample*	*Output*	*Economies of scale* (*mean point values in parenthesis*)
Fabbri (1998)	Variable cost function, translog form	9 urban and intercity bus companies, Region Emilia Romagna, 1986-1994	Vehicle-kms	- high economies of size in both the short (1.66) and the long run (1.71); - importance of size economies decrease with increasing firm dimension.
Fazioli, Filippini and Prioni (1993)	Total cost function, translog form	40 intercity bus companies, Region Emilia Romagna, 1986-1990	Seat-kms	- high economies of size (1.70) and network density (2.61); - importance of size and network density economies decrease with increasing company dimension.
Levaggi (1994)	Variable cost function, translog form	55 urban bus companies, Italy, 1989	Passenger-kms	- very high economies of use intensity in both the short (8.29) and the long run (5.40); - relevant size economies in the short run (1.43) but weak size diseconomies in the long run (0.92); - relevant network density economies in the short run (1.38) but weak network density diseconomies in the long run (0.89).

Source: Piacenza (2000)

Table 3. Descriptive statistics by type of service: urban, intercity, and mixed companies

TYPE OF SERVICE:	OVERALL SAMPLE				URBAN (18 COMPANIES)				INTERCITY (15 COMPANIES)				MIXED (12 COMPANIES)			
	mean	*vi* [a]	*Min*	*max*	*mean*	*Vi* [a]	*min*	*max*	*Mean*	*Vi* [a]	*min*	*max*	*mean*	*vi* [a]	*Min*	*max*
VC [b] (millions Lire)	56,422	1.27	668	442,364	54,723	1.71	668	442,364	51,591	1.02	13,341	261,821	65,011	0.82	3,866	228,909
Y [c] (millions)	437,709	2.82	36	8,156,749	544,008	3.28	36	8,156,749	242,893	1.22	11,671	1,055,645	521,781	1.73	1,974	3,441,564
K [d]	257	0.96	7	1,582	223	1.47	7	1,582	247	0.61	56	573	320	0.58	24	771
P_L (millions Lire/worker)	70.24	0.08	56.31	85.90	69.65	0.08	56.31	83.12	71.40	0.08	60.45	85.90	69.69	0.07	62.90	78.85
P_F (Lire/liter of diesel oil)	1,056	0.10	625	1,358	1,041	0.10	625	1,297	1,061	0.09	886	1,232	1,070	0.09	918	1,358
P_{MS} (Lire/seat-km)	16.24	0.37	6.77	35.26	15.34	0.39	6.97	32.18	17.12	0.37	6.77	33.13	16.47	0.33	8.64	35.26
SP (Kms/h)	23.12	0.34	13.00	45.00	16.45	0.16	13.00	25.00	29.44	0.22	17.00	41.50	25.23	0.28	14.76	45.00
Factor cost-shares:																
S_L (labor)	0.67	0.10	0.49	0.85	0.69	0.11	0.49	0.80	0.67	0.10	0.55	0.85	0.65	0.08	0.52	0.74
S_F (fuel)	0.08	0.19	0.04	0.12	0.08	0.14	0.05	0.10	0.09	0.21	0.04	0.12	0.09	0.15	0.06	0.12
S_{MS} (materials and services)	0.25	0.28	0.10	0.45	0.23	0.34	0.13	0.45	0.24	0.24	0.10	0.35	0.26	0.23	0.17	0.42

[a] The variability index (*vi*) has been calculated as the ratio of the standard deviation to the mean.
[b] Variable operating cost (*VC*) is the sum of labor, fuel, and materials and services expenses.
[c] Output (*Y*) is measured as the product of total places offered times total kilometers travelled in each year.
[d] Capital (*K*) is computed as the number of vehicles in the rolling stock weighted by an average-fleet-age index.

Table 4. SUR estimation of the Translog cost system [1]-[3]

Regressor [a]	*Coefficient*	*Standard Error*	*T-Ratio[Prob]*
Constant	25.1529	.035892	700.788[.000]
$\ln Y$	.452817	.038913	11.637[.000]
$\ln K$	.168570	.082807	2.036[.043]
$\ln P_L$	.629433	.007421	84.817[.000]
$\ln P_{MS}$	.286963	.006664	43.059[.000]
$\ln P_F$	.083604	.001821	45.908[.000]
$\ln SP$	-.126729	.051529	-2.459[.014]
$\ln Y*\ln P_L$	-.038308	.007640	-5.014[.000]
$\ln Y*\ln P_{MS}$	.040785	.006846	5.957[.000]
$\ln Y*\ln P_F$	-.002477	.001853	-1.337[.182]
$\ln K*\ln P_L$	.078934	.016142	4.890[.000]
$\ln K*\ln P_{MS}$	-.084910	.014460	-5.872[.000]
$\ln K*\ln P_F$	.005977	.003901	1.532[.126]
$\ln Y^2$	-.057788	.033500	-1.725[.085]
$\ln K^2$	-.297020	.166422	-1.785[.075]
$\ln Y*\ln K$	.128166	.074196	1.727[.085]
$\ln P_L*\ln P_{MS}$	-.137248	.005056	-27.145[.000]
$\ln P_L*\ln P_F$	-.033165	.005484	-6.048[.000]
$\ln P_{MS}*\ln P_F$	-.014870	.002047	-7.265[.000]
$\ln P_L^2$	.170414	.007450	22.873[.000]
$\ln P_{MS}^2$	.152118	.005338	28.501[.000]
$\ln P_F^2$	.048036	.005340	8.995[.000]
$\ln Y*\ln SP$	-.101721	.044139	2.305[.022]
$\ln K*\ln SP$	-.241315	.088670	-2.721[.007]
$\ln P_L*\ln SP$	-.050958	.012004	-4.245[.000]
$\ln P_{MS}*\ln SP$	.024563	.010720	2.291[.023]
$\ln P_F*\ln SP$	.026395	.002892	9.128[.000]
$\ln SP^2$	-.289734	.130746	-2.216[.027]
DINTC	-.115614	.024632	-4.694[.000]
DMIX	-.150252	.022422	-6.701[.000]

Equation	R^2	*F-value[Prob]*
$\ln VC$	.9862	5995.82[.000]
S_L	.5555	132.26[.000]
S_F	.5269	46.02[.000]

[a] All the independent variables have been divided by their sample mean value before the transformation in logarithms.

Table 5. Technology characteristics evaluated at the sample mean (average firm) [a]

Returns to scale	SHORT-RUN	2.21 (0.19)	LONG-RUN	1.84 (0.04)
Network speed cost elasticity		-0.13 (0.05)		
Service-specific cost elasticities [b]	INTERCITY	-0.11 (0.02)	MIXED	-0.14 (0.02)

Morishima elasticities of input substitution

	$j = L$	$j = F$	$j = MS$
$i = L$	-	0.37 (0.09)	0.25 (0.16)
$i = F$	0.33 (0.07)	-	0.29 (0.17)
$i = MS$	0.25 (0.14)	0.37 (0.08)	-

Own-price input elasticities

L, P_L	F, P_F	MS, P_{MS}
-0.10 (0.03)	-0.34 (0.08)	-0.18 (0.13)

[a] Estimated asymptotic standard errors in brackets.

[b] Service-specific cost elasticities represent the percentage effect on variable costs due to the shift of firm production from urban to intercity or mixed service. Following Halvorsen and Palmquist (1980), these elasticities are computed as [exp(*DINTC*) -1] and [exp(*DMIX*) -1] respectively.

Table 6. Estimated average variable costs by type of service and firm size [a]

	URBAN	INTERCITY	MIXED
SMALL SIZE	0.93	0.61	0.49
MEDIUM SIZE	0.42	0.26	0.24
LARGE SIZE	0.23	0.14	0.11

[a] Size classes were constructed on the basis of the number of workers (n.w.) employed by firms: small size for n.w. < 200; medium size for n.w. ∈ [200, 550]; large size for n.w. > 550.

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