

# **Standard costs of the regional rail transport in Italy: evidence from a (wild) bootstrap analysis**

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## **Abstract**

The paper presents a top down econometric model to estimate the standard cost in Italian regional public rail passenger transport services (LPTR), depending on (quantitative and qualitative) characteristics of the service which entail differences in the unit cost. Although the sample is large the number of observations is small. Hence we employ wild bootstrap methods in order to enhance the statistical significance of the estimates. The results highlight the crucial role of the number of seats offered on average per ride, of commercial speed, of the service size and of the overall length of the rail tracks where the service is deployed. The model also shows the positive link between investment in rolling stock and the unit cost of the service. Finally, we propose regulatory adjustments to the model to take into account policy targets regarding the fair allocation of public LPTR funds among regions.

## **Keywords**

rail passenger transport, standard costs, cost models, local public transport, fiscal federalism

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## 1. Introduction

In the past two decades, many EU-member States (e.g., Sweden, Finland, Germany, France and the United Kingdom) have introduced competitive tendering procedures in the local public transport (LPT) industry, in order to boost efficiency in service provision, enhance productivity and reduce LPT firms, losses and/or local authorities spending. In this process - regulated by the European Directive 1370/07/EU - the Italian Government devised a number of interventions. The source of financing moved to regions in 1996 and back to the central government in 2011. Regions are once again recipients of government funds, albeit allowed to increase LPT funding out of their own tax revenues. Local authorities and LPT operators are required to sign a formal agreement (service contract), which defines terms of operation (i.e. service quantity, time schedule etc.), passenger fares and subsidies. The industry reform touched upon two important dimensions: how public funds are allocated to Regions and to Local Authorities, and how to define the maximum economic compensation that can be required by any LPT firm which takes part in competitive tendering procedures or which is selected without competitive bidding (“in house providing”).

Standard costs were introduced in the Italian legislation as far back as 1997, in the pursuit the of a fairer distribution and a more efficient use of (scarce) public resources. However, standard costs were never implemented to present days.. In 2014 a working group was jointly set up by the central government, regions and local authorities in order to work out an appropriate method for calculating standard costs of LPT services and for the use of standard costs in the allocation of public funds to Regions<sup>1</sup>. In summary, the standard cost should reflect the cost of a LPT service provided by an efficient operator and given a specified service quality (where the “efficiency levels” are defined on the basis of the activities and costs of several operators and/or of knowledge of the industrial process for the provision of LPT services). Several recent legislative interventions have provided details on how standard costs should be applied to the LPT sector.

This paper develops a workable model for the (top-down) econometric estimation of the standard cost in LPT services<sup>2</sup>. In many Italian regions rail services are provided by just one train operator, typically a regional division of Trenitalia, a state-owned train company. In some regions there also exists one (or more than one) small network operated by independent region-owned train companies. Despite being subsidiaries of the same national company, the regional divisions of Trenitalia serve markedly different networks as for size, service density and commercial speed. They also make use of different rolling stocks. In principle then the actual unit costs may vary widely among different regional divisions of Trenitalia as well as between Trenitalia and other companies.<sup>3</sup>

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1 The authors of the present paper, as members of the working group, were in charge of the modelling strategy and of the actual estimation of the model.

2 We also worked out two different methods for calculating standard costs of LPT bus services (Avenali, Boitani *et al.*, 2016, 2018).

3 All Trenitalia divisions share the same labour contract, whilst other companies may have entered different second tier contracts.

The contribution of the paper to the literature and the policy debate is twofold, on the one hand the proposed methodology can be suitably used by policy makers in defining new methods for the allocation of public funds to Regions. On the other hand, it provides a benchmark for the definition of the economic compensation to be set as auction-base in LPTR tendering procedures. In such a way, LPTR firms will be encouraged to promote their efficiency on the principle of yardstick competition (Shleifer 1985; Mizutani 1997; Mizutani et al. 2009). In fact, the standard cost reflects the cost of the service regardless of the particular provider. Local Authorities might then acknowledge to LPTR service providers a compensation that matches the costs of a reasonably efficient operator and not the specific costs of the firm supplying the service.

In this paper the unit standard cost is defined as the economic cost per seat kilometre (net of out-of-service, non-revenue generating seat kilometres) and it is estimated from data collected from LPTR operators in Italy covering around 96% of the total amount of regional train kilometres produced in 2012, or around 220 million train kilometres. The approach adopted in this work aims at identifying the (quantitative/qualitative) features of the service which validate significant differences in the unit standard cost. To achieve this goal, the technological characteristics of the production process and the used resources have been studied by conducting interviews with engineers and managers of the LPTR operators in our sample. Finally, in order to implement some policy targets, we show how the model could be adjusted with suitable regulatory constraints in the allocation of the national public fund for the LPT among Italian Regions.

As for the empirical analysis, the crucial problem we face is that our sample size is quite small. The traditional statistical inference is based on the central limit theorem (asymptotic theory) which could be inappropriate when the sample size is small. For that reason, our statistical inference is based on the bootstrap (Efron 1979), that has been shown (Hall 1992) to deliver much more accurate inference in finite samples (while in large sample is at least as accurate as the approximation obtained from first-order asymptotic theory)<sup>4</sup>. We perform several tests to check the robustness of our results.

The paper is organized as follows. Section 2 contains a short review of the relevant literature. Section 3 identifies cost categories which define the standard cost model and the key aspects of the production process of local public rail transport services. Section 4 describes the data set and variables. Section 5 presents the model and the results, while Section 6 develops some test examples and policy implications. Section 7 concludes.

## 2. Literature Review

There exist a large body of literature on the topic of the present paper. The pioneering works aimed at describing the LPTR industry estimated basic cost/output relations (Borts 1960; Griliches 1972). Further studies focused on scale and density economies and introduced in the cost function size variables such as track miles, rolling stock size and average service speed (Keeler 1974; Braeutigam *et al.* 1984) this paper find unexploited economies of traffic

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<sup>4</sup> However, the idea to adopt bootstrap inference in transport research is not new, see for example Bilotkach et al. (2015), and Maness and Cirillo (2016).

density for most railroads, but constant long-run returns to scale. Caves *et al.* (1980, 1981, 1985) make use of multi output translog cost functions to estimate density and scale economies and productivity growth in US and Canadian Railways. Preston and Nash (1993) introduce traffic density in the translog cost function to analyse and compare density and scale economies in the European Railways. Although these studies employ different output measures (such as train-kilometres, car-kilometres, car-hours, ton-kilometres for freight), they all find substantial increasing returns to density and decreasing returns to scale. Kim (1987) uses passenger kilometres and ton-kilometres as output measures and finds that the US railroad industry suffered from diseconomies of scope associated with the joint production of freight and passenger services while detecting product-specific economies of scale with respect to the production of both freight and passenger services. De Borger (1991) provides an early application of the hedonic output aggregation method to the railroad industry and introduces operating characteristics (related to the length of the network and the load factor) in the cost function. Also Braeutigam *et al.* (1982) estimate a hybrid cost function where engineering process functions were used to provide observations on the speed of the service.

It is worth noting that many papers jointly analyse passenger and freight services and only more recently some papers have focused on passenger services only. Viton (1980) analyses rapid mass transit services in US and Canada and finds, differently from previous works, diseconomies of density related to services delivered in metropolitan congested areas. Filippini and Maggi (1992) discuss the efficiency of the Swiss Private Railways. They find that most of the Swiss private railway companies operate at an inappropriately low scale and density. Savage (1997) estimates the costs for US urban mass transit systems and finds large economies of density in operating costs. These economies become even more substantial when the rail infrastructure maintenance costs and capital costs are incorporated. Mizutani (2004) estimates the cost of privately owned passenger railways in Japan and finds that, on average, the costs of public railways are higher than those privately owned. Daniel *et al.* (2010) estimates costs for a single operating company in the Netherlands for a large number of years. They find that seats-kilometres is the output measure that yields the best statistical results when estimating costs of passengers services, as regards the presence of density economies the results are ambiguous (they cannot reject the hypotheses of constant return to density).

Wheat and Smith (2014), analyse train operating companies in the UK and, in order to model the cost structure of that industry, employ an hedonic cost function with three outputs (route-kilometres, train-hours and the number of stations) and nine characteristics of train services including average speed and load factor. They discuss whether infrastructure inputs should be included in the cost analysis and argue that, while those inputs are difficult to measure, their inclusion would divert the focus from train operating companies to the rail industry as a whole. Thus, they choose to leave infrastructure inputs out of their analysis.

### 3. Cost categories and drivers

In this section we identify the cost categories to be included in our cost model (the sample data are summarized in Table 3): (i) operation and maintenance costs<sup>5</sup>; (ii) administrative costs and other overheads; and (iii) the cost of capital. The cost of capital is based on an estimation of the pre-tax Weighted Average Cost of Capital (WACC) of the LPTR sector, namely, the minimum return on the net invested capital that has to be generated to fully reward all providers of financial resources, that is, debt and equity (Damodaran, 2012). We follow Filippini and Maggi (1992, 1993) in considering the net value of trains and maintenance facilities as a good proxy of the Net Invested Capital.

In order to calculate the economic cost for the provision of a specific transport service, the value of the total number of employed vehicles is accounted for, including those owned by the train company (gross of non-repayable public funds), those rented/leased, and those given to LPTR firms free of charge by a Local Authority. Since operators may use different depreciation periods for their fixed assets, the depreciation rate has been normalized by considering a uniform depreciation period, so as to fairly compare the production costs of such services. A consensus estimate of the average technical life of any fixed asset was formed within the above mentioned working group: (i) by taking into account the physical life of each asset and the expected technology enhancements; (ii) by assuming that ordinary maintenance is regularly carried out. Furthermore, possible extraordinary maintenance of the assets is usually capitalized and thus it is considered as an additional asset. Wrapping up, we estimated a depreciation period of 30 years as for trains and for the capitalized extraordinary maintenance of trains and a slightly longer depreciation period for the depots: 32.5 years.

Since most of the interviewed operators do not apply the international accounting standards, they are unable to determine the fair values of their assets. Depreciation reflects just a nominal amount of the assets value yearly consumed in the production process. Consequently, in order to assess the correct economic value of fixed assets, we deem appropriate to apply the current cost accounting method. In this case, we estimate the current market value of the assets by multiplying the gross book value by a suitable deflation index (provided by the Italian National Institute of Statistics), depending on the age of the asset. Finally, the overall economic cost of any observed service is divided by the number of seat kilometres to define an effective measure of the unit cost of the service. Indeed, the observed services presents a large variance in terms of the number of offered seats per ride.

#### 3.1 Key aspects of the production process

In order to classify the main drivers of total cost and characterize the cost function to be estimated, it is necessary to analyse the technological features and the inputs involved in the production process. To this purpose, interviews have been conducted with engineers and managers of LPRT firms in our sample. The following observations emerged.

*Observation 1.* One of the main characteristics of local public transport services is the commercial speed, which is the average speed at which the service is delivered to passengers. As for the specific LPTR services under scrutiny we measure commercial speed as the total

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<sup>5</sup> Due to missing data and non-homogeneity of the available data on the access charge to the rail network operator for passenger trains, our cost model does not take into account the access charge cost component.

number of train kilometres divided by the journey time (from the departure station to the final destination of each train). The commercial speed is perceived by passengers as an hedonic characteristic of the service, and, at the same time, it summarizes a plurality of elementary aspects of the service (such as, the average distance between consecutive stops, the average slope of the rail tracks, the average level of track maintenance, etc.).

*Observation 2.* In LPTR services, the economic cost of the rolling stock and of the maintenance facilities (depreciation and relative cost of capital, charges for rents and leases) are the main component of a service cost, averaging about 40% of total cost. Table 3 shows some features of the detected services and highlights that the most significant part of this cost component refers to the rolling stock. The annual productivity of trains depends, on the one hand, on the commercial speed at which the service is provided, and, on the other hand, by the ratio between the service size (that is, the amount of revenue train kilometres) and the extension of the rail network. In particular, although trains can be used by multiple drivers on the same day (a single daily machine shift can unfold along more than one driver shift), a reduction in commercial speed reduces the annual number of kilometres that each train can run. In addition, the more a railway network is interconnected and large, the more the machine shifts can be optimized through dedicated software. In such cases, it is possible to significantly raise the train kilometres supplied without increasing the number of trains. Thus, the cost of the rolling stock is shared across a larger number of train kilometres and the cost per train/seat kilometre of service decreases. Therefore, an intensive use of the rolling stock on the railway network may signal lower cost per train/seat kilometre, essentially due to economies of density.

*Observation 3.* On board personnel represents on average 25% of total costs in the Italian LPTR industry. The number of train-km per year each driver is able to produce depends significantly on the commercial speed and on the length of each journey. Therefore, an increase in commercial speed (for example by reducing the number of stops), or lengthening some routes may allow an increase in drivers, productivity. In addition, the services provided on short routes are often characterized by short-distanced stops and thus lower commercial speed. Since on board personnel is an important driver of total cost and it is strongly influenced by commercial speed, one can expect that the marginal effect of commercial speed on the cost per train/seat kilometre is much more important in services with low commercial speed than in those with higher commercial speeds.

*Observation 4.* The energy consumption (in the case of electrified lines) or fuel (in the case of diesel powered trains) is more intense for services with close stops (and therefore characterized by lower commercial speed), because of the frequent restarts and accelerations that trains are subject to. However, regarding the electric power consumption, network operators typically impute an energy cost per kilometrekilometre travelled by trains, and therefore independent of the commercial speed. Furthermore, in most cases, the non-electrified lines represent a small part of the detected traffic. Therefore, we presume that a marginal increase in commercial speed can result in a limited reduction of energy consumption. However, for any commercial speed, the powertrain cost per train kilometre of a diesel-driven train results quite higher than that of an electric-driven one (with similar capacity).

*Observation 5.* Operators (or consortia of operators) above a certain size may be advantaged or disadvantaged in the acquisition of certain production inputs; thus, pecuniary economies or diseconomies of scale may arise. For example, through well-planned tenders for the procurement of a sufficient number of trains and/or train parts, it is possible to purchase goods/services at lower unit prices. On the other hand, labour unions can obtain better contractual terms (thus determining a higher driving cost per hour), thanks to a stronger bargaining power in second tier negotiations in cases when the train company is large. Therefore, since the rolling stock and the crew members are two relevant cost items, the overall (pecuniary) effect of the scale on the unit cost due to changes in the unit price of inputs is not univocal and easily predictable.

#### 4. Data and variables

The survey was carried out by means of a specific questionnaire containing detailed economic and transport information. The detection regards accounting and transport data relative to year 2012, resulting in 29 observations, corresponding to 34 service contracts, referred to as service bundles hereafter. A service bundle is a set of one or more service contracts for which the firm is able to measure only jointly its direct and indirect costs. The collected data represent approximately 220,000,000 train kilometres, which account for over 95% of the total supply of regional railway services in Italy in 2012.

**Table 1. Number of train kilometres provided by firms included in the sample**

<i>Region</i>	<i>Detected train revenue kilometres</i>	<i>Total train kilometres</i>	<i>% train kilometres detected over total</i>
Abruzzo	3,838,603.61	4,478,465.61	85.7%
Basilicata	2,566,122.21	2,566,122.21	100%
Calabria	6,586,791.06	7,832,110.46	84.1%
Campania	15,531,826.16	15,531,826.16	100%
Emilia Romagna	17,272,166.82	17,272,166.82	100%
Friuli V. Giulia	2,923,542.14	3,157,686.14	92.6%
Lazio	21,094,100.32	21,094,100.32	100%
Liguria	6,438,471.64	6,438,471.64	100%
Lombardia	38,232,145.00	38,232,145.00	100%
Marche	3,821,848.56	3,821,848.56	100%
Molise	1,934,544.75	1,934,544.75	100%
Piemonte	18,898,112.47	19,036,692.47	99.3%
Puglia	8,846,647.99	12,996,689.99	68.1%
Sardegna	4,431,175.97	4,431,175.97	100%
Sicilia	9,958,742.69	9,958,742.69	100%
Toscana	22,740,882.63	22,740,882.63	100%
Trento-Bolzano	8,179,427.80	8,179,427.80	100%
Umbria	3,672,025.40	5,922,965.40	62.0%
Valle d'Aosta	1,703,636.53	1,703,636.53	100%
Veneto	18,551,791.41	18,551,791.41	100%
TOTAL	217,222,605.16	225,881,492.56	96.2%

Table 1 highlights the relevance of the detected data showing the amount of train kilometres detected compared to the total amount of train kilometres offered in Italy in 2012.

Table 2 presents the descriptive statistics for some variables characterizing the service bundles included in the sample, showing a wide gap between minimum and maximum values of each variable under scrutiny, independently of the network size.

**Table 2. Some descriptive statistics**

	<i>Mean</i>	<i>Min</i>	<i>Max</i>	<i>Std. dev.</i>
Train kilometres (mln)	7.49	0.58	38.23	8.35
Seat kilometres (mln)	2,655.19	86.40	17,745.93	3,879.90
Commercial speed	51.82	30.80	71.65	10.79
Train productivity (train overall kilometres/used trains)*	97,056.14	20,224.80	163,772.91	35,300.53
Driving hours	654.79	359.03	1,077.31	155.68
Seats per ride	263.98	91.00	550.00	135.66

\* Train overall kilometres includes those run out of the service necessary to bring trains from depots to the station which the service to the users starts from. The amount of trains includes the number of train used during peak hours plus redundancy for possible train breakdowns and programmed maintenance.

Table 3 shows the average incidence of different cost elements on the cost per seat kilometre as emerging from the survey.

**Table 3. Cost per seat kilometre: components**

<i>Component (€/skmskm)</i>	<i>Mean</i>	<i>Min</i>	<i>Max</i>	<i>Std. dev.</i>
Driving personnel	0.00897	0.00380	0.02360	0.00529
Non driving crew	0.00664	0.00220	0.01930	0.00471
Cost of fuel	0.00332	0.00009	0.01077	0.00335
Cost of electric power	0.00207	0.00048	0.01208	0.00284
Rolling stock (depreciation, rent/leasing, etc.)	0.01068	0.00510	0.04140	0.00739
Maintenance, general costs and other production costs	0.01828	0.00790	0.04360	0.00964
Cost of capital	0.01357	0.00090	0.04460	0.01029

Note that the maintenance cost includes the cost for outsourced maintenance, the cost of spare parts, the cost of personnel for in-house maintenance, depreciation of equipment, facilities and buildings used for in-house maintenance (net of capitalized extraordinary maintenance). The cost for rolling stock includes depreciation of capitalized maintenance work on the trains. Overhead costs include the cost of dedicated personnel. Other production costs including all those cost pertaining to the industrial production of the service, such as, for example, electronic ticketing systems and other ICT-related costs not considered elsewhere are included in the overhead costs.

## 5. Methodology and empirical analysis

The model we present is meant to be readily usable by local authorities in setting the maximum economic compensation in competitive tendering procedures. Based on

observations presented in Section 3, we build a multiple regression model of the unit cost of LPTR services in 2012, by employing the following explanatory variables:

- $Ns$ : number of seats per ride.
- $Sp(km/h)$ : commercial speed. This is a qualitative (hedonic) characteristic of a service, which can be barely controlled by the operator.
- $T$ : rail turnover or network turnover or intensity in usage of rail tracks. Let  $Skm$  be the seat kilometres (in millions) and  $Rkm$  be the kilometres of rail tracks used to produce the rail service. Thus, rail turnover  $T$  is the ratio between  $Skm$  and  $Rkm$ .
- $Askm(€/skm)$ : degree of renewal of the fleet. This variable is defined as the ratio between a monetary value and the number of seat kilometres. In the case whereby the rolling stock is completely owned by the operator, the monetary value is the sum of all depreciations of the owned vehicles (by assuming a 30 years depreciation life and including the depreciation of the capitalized maintenance of the trains). This variable identifies a qualitative characteristic under the control of the LPT operator. To have an upper bound to the degree of renewal of the fleet for Italian firms, we made use of consensus estimations of the standard market values (in 2012) of several newly equipped train types. These estimates include the present value of trains, expected capitalized maintenance through their life cycle (e.g. a 144 seats-diesel powered train is estimated at 4,162,500 euros, a 810 seats-electric energy powered train is estimated at 12,262,500 euros). Starting from these values, the depreciation which can be applied to compute the degree of renewal ranges from a maximum of 840.78 euros per seat in the case of a single decker train (either diesel or electric), to a minimum of 532.32 euros per seat for a double decker train (either diesel or electric).<sup>6</sup> For instance, let us consider a case where a regional rail service is delivered with one single decker train with 180 seats and one double decker train with 480 seats; assume also that the 180 and 480 seats trains run 70,000 and 90,000 revenue kilometres per year respectively. Then, the standard degree of renewal of this fleet is equal to  $\frac{180 \times 840.78 + 480 \times 532.32}{180 \times 70,000 + 480 \times 90,000} = 0.007291 \text{ € / srkm}$ .
- $Di$ : percentage of seat kilometres powered by diesel. It is the ratio between the diesel-powered seat kilometres and the overall seat kilometres.

We focus on modeling the main (quantitative/qualitative) characteristics of the services which cause significant differences in the unit cost. The modeling choice is justified by observing that a single train operator (Trenitalia) is running most of the contracts in our sample and unit input costs are then unlikely to explain the variability of costs within the sample.

### 5.1 The econometric model

As noted, the Italian LPRT services have a large variance in terms of the number of seats available per offered ride. In order to determine a statistically significant and robust cost model we deemed appropriate to estimate the economic cost of the service per seat kilometre.

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<sup>6</sup> For example, the value of a (either powered) train with 180 seats on one floor, included the present value of its expected capitalized maintenance through its life cycle, is estimated equal to  $180 \times 840.78 \times 30 = 4,540,212.00 \text{ €}$ .

We chose the model presented in this section after several trials estimating different functional forms and equations including different sets of explanatory variables. For instance, we tested models which also take into account as regressors (i) the quantity of driving hours, (ii) the quantity of driving personnel, (iii) the quantity of revenue kilometres produced yearly by a train, (iv) the quantity of used trains or the quantity of used coaches, and (v) the quantity of seat kilometres. We estimated linear and piece-wise linear functions and finally selected the best fitting functional form and the set of explanatory variables that proved to be highly statistically significant.

We obtain the standard value of the cost per seat kilometre, denoted by  $Cskm$ , by using an OLS estimation and by taking into account the explanatory variables identified above. The explanatory variables to be included in the regression were chosen by taking into account their role in the production process.

The estimated model is:

$$Cskm_j = \alpha + \frac{\beta}{Sp-28} + \gamma \times T + \delta \times Askm + \theta \times Di^2 + \varepsilon_j \quad (1)$$

where  $j=1, \dots, N$ ,  $N$  is the sample size,  $\varepsilon_j \in (0, \sigma_j^2)$  with possibly  $\sigma_j^2 \neq \sigma_t^2$  for  $j \neq t$ .

The model indicates that the impact of commercial speed on the unit cost is modelled through a hyperbolic function; the asymptote of the regressor  $1/(Sp-28)$  has been selected in order to maximize the fitness of the regression and the significance of the parameters. Obviously, each of the detected services has a commercial speed exceeding 28 km/h and thus the term  $Sp-28$  is always positive for these services. For predictive purpose the model should not be applied to trains that do not reach the 28 km/h threshold. However, to the best of our knowledge, no rail service in Italy presents average commercial speed below such a threshold. Note that from equation (1) we can easily obtain the expression of the standard cost per revenue kilometre ( $Ctrkm$ ) by taking into account the average number of seats per ride ( $Ns$ ):

$$Ctrkm = Cskm \times Ns \quad (2)$$

Table 4 shows the results of the estimated model (1).

To obtain robust empirical evidence there is an issue to be solved: the small sample size, that is, 29 observations. We address that issue by using bootstrap methods. These were originally introduced by Efron (1979) and have become a quite standard approach to obtain robust inference when the sample size is small. Davidson and Mackinnon (2004, p. 171) for the regular bootstrap and Davidson and Flachaire (2008) for the wild bootstrap show very good performance of the bootstrap using a sample size of 10 observations.

**Table 4. Standard cost per seat kilometre: regression results**

<i>Regressor</i>	<i>Coefficient</i>	<i>Estimates (std. err)</i>	<i>Asy. p-value</i>	<i>Bootstrap p-value</i>
Constant: 1	$\alpha$	0.02716*** (0.009)	0.007	0.000
Commercial speed: $\frac{1}{Sp-28}$	$\beta$	0.24975** (0.060)	0.000	0.048

Network turnover: $T$	$\gamma$	-0.00349*** (0.001)	0.003	0.010
Degree of renewal of the fleet: $Asrkm$	$\delta$	3.52342*** (0.804)	0.000	0.009
Percentage of diesel-powered seat kilometres: $Di^2$	$\theta$	0.02816** (0.013)	0.053	0.047
n. obs. = 29 F = 42.81 R <sup>2</sup> = 0.8771		Breusch-Pagan test for heteroskedasticity: LM=9.05 p-value:0.059		

\*\*\*=Significant at 1% level; \*\*=Significant at 5% level; \*=Significant at 10% level, based on HC2 standard errors and 9999 wild bootstrap replications.

After fitting a regression model, when the regression residuals are homoscedastic, the appropriate bootstrap is the regular bootstrap, while if the regression residuals display heteroscedasticity, the appropriate bootstrap method is the so-called wild bootstrap (see for details Davidson et al. 2007 and Davidson and Flachaire 2008). In our analysis, we estimate a regression model and we test for homoscedasticity (the Breusch-Pagan test for heteroskedasticity is reported in table 4 and 5), and if we reject the null hypothesis of No-homoscedasticity, we compute the robust standard errors (see Davidson and Mackinnon 2004) and the p-values by the wild bootstrap. In our empirical analysis we used 9999 (wild) bootstrap replications. For completeness, close to the bootstrap p-values, the standard p-values based on the asymptotic approximation (Gaussian distribution) have been reported.

The estimated coefficients are reported in Table 4. As we can observe, all the coefficients are highly statistically significant.

## 5.2 Causes of variability in unit standard costs

Let us discuss in this section the impact of each explanatory variable identified in equation (1) on the unit standard cost.

### 5.2.1 Commercial speed

The first effect is related to the commercial speed (expressed in km/h), that, by increasing, produces a decrease of the unit standard cost. More in detail, the functional form that the estimated unit cost tends to assume, with respect to this variable, is L-shaped. In other words, a marginal increase in commercial speed is much more effective in reducing the unit cost of services characterized by lower commercial speed.

### 5.2.2 Network turnover

A second effect is due to the rail turnover that it is measured by the ratio between seat kilometres and the overall length (in kilometres) of each railway network. The higher this variable, the higher the use of that rail infrastructure by each rail operator. The shape of the function is downward sloping as the rail turnover raises; therefore, increasing the scale of the service on the same railway lines implies a decrement in the unit standard cost  $Cskm$ ; therefore, increasing returns to density occur.

As observed in Section 3, the impact of the rail turnover on the unit standard cost  $Cskm$  could depend on a raise of train productivity as the network turnover increases. To support such an assumption, we performed a regression analysis that links the average number of

revenue kilometres produced yearly by a train with commercial speed and the network turnover. We observed that the productivity of trains raises with the commercial speed of the service and with the logarithmic of the rail turnover (see the Appendix). Therefore, as the rail turnover increases, the yearly train productivity raises but at decreasing marginal rates. For instance, a 70 km/h commercial speed service and with a rail turnover of about 5 million of seat kilometres per track kilometre presents a yearly average productivity per train equal to 146,362.62 km, while a service provided at 45 km/h commercial speed and with a rail turnover of about 1 million of seat kilometres per track kilometre has a yearly train productivity equal to 61,049.27 km.

### 5.2.3 *Renewal of the rolling stock*

The variable  $Ask_m$  is a monetary measure of the degree of renewal of the used rolling stock. It can be considered as a proxy of the quality perceived by the users of the service. Depreciation and rent/leasing of the fleet reflects, in fact, one of the most important and expensive components of the quality of service provided to the users. In particular, the functional form that estimates the unit standard cost tends to assume, with respect to the degree of renewal, an increasing linear shape.

### 5.2.4 *The diesel-powered rolling stock*

Variable  $Di$  takes into account the impact on the unit standard cost of the share of diesel powered trains. Indeed, the powertrain cost per train kilometre is larger in the case that the train is powered by diesel than by electric energy. Moreover, the maintenance cost per seat of a diesel-powered train is usually higher than of an electric-driven train.

In particular, the unit standard cost tends to increase less than linearly as the percentage of the diesel-powered seat kilometres raises. Thus, where the share of seat kilometres offered through diesel-powered trains is small, the marginal increment of the unit standard cost is low as the cost for diesel-train maintenance and fuel have a little impact on the overall cost. Where the share of seat kilometres offered by means of diesel-powered trains is close to one, the marginal increase of the unit standard cost becomes high since the impact of the cost for diesel-train maintenance and fuel is large.

## 6. **Test examples and policy implications**

A simple numerical example can help in understanding the features and the policy implications of the proposed model (from now on, Example A). Let us take a train company producing 25 million electric-powered train kilometres per year over a network 1,600 km long, where the rolling stock offers on average 435 seats per ride (i.e. 10,875 million seat kilometres are offered to the users in one year). Let the commercial speed be 50 km/h, and the degree of renewal of trains equal to 0.00577 €/skm. Thus, making use of equation (1) and plugging in the estimated parameters from Table 4, the standard cost of this service per seat kilometre turns out to be equal to:

$$C_{skm} = 0.02716 \underbrace{\frac{+0.24975}{50-28}}_{\text{commercial speed effect}} - 0.00349 \times \underbrace{\frac{10'875}{1'600}}_{\text{network turnover effect}} + \underbrace{3.52342 \times 0.00577}_{\text{degree of renewal effect}} + 0 \times 0.02816 = 0.03512 \text{ € / skm}$$

From equation (2) the cost per seat kilometre can be easily converted into the cost per train kilometre:

$$C_{tkm} = 435 \times C_{skm} = 15.28 \text{ € / tkm}$$

Starting from Example A, the ensuing figures show the effect on the standard cost per train kilometre of the commercial speed, of the rail turnover and of the size of the offered service. Figure 1 plots the (*coeteris paribus*) relation between the standard cost per train kilometre and commercial speed (in a range of values between 35 km/h and 70 km/h). Figure 2 plots shows the (*coeteris paribus*) relation between the standard cost per train kilometre and the rail turnover (in a range of values between 6.5 and 10.5). Finally, Figure 3 plots the relation between the standard cost per train kilometre and the service size (in a range of values between 23 and 35 million of train kilometres).

Note that, although the model does not explicitly define a link between the standard cost and variables that are under direct control of the train companies (such as, for example, the driving hours or the number of drivers), LPRT operators are still encouraged to increase their efficiency through the mechanism of *yardstick competition*. In fact, those operators who can provide the service at a unit costs lower than the standard cost agreed in the service contract will gain profit margins. Furthermore, we remark that the model is based on variables which cannot be easily manipulated by LPRT firms and thus the model is quite robust with respect to possible opportunistic behaviour.

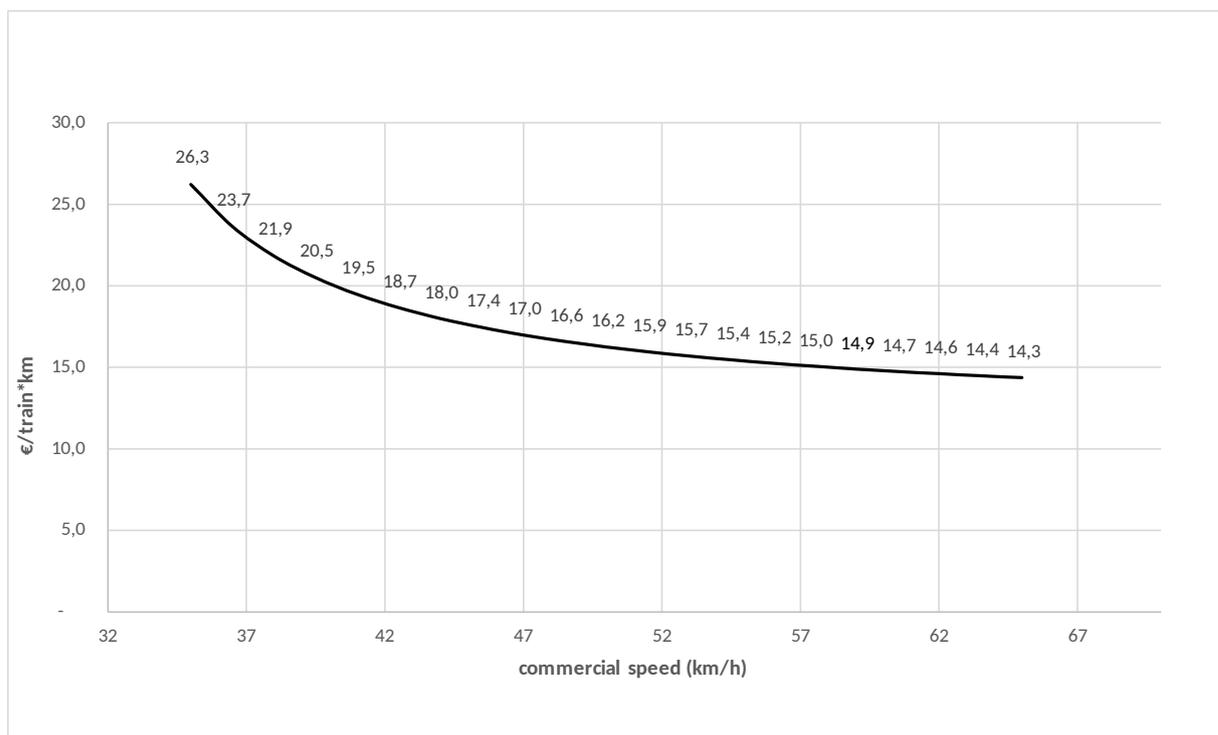


Figure 1. Example A: simulating the effect on  $Ctkm$  of an increase in commercial speed

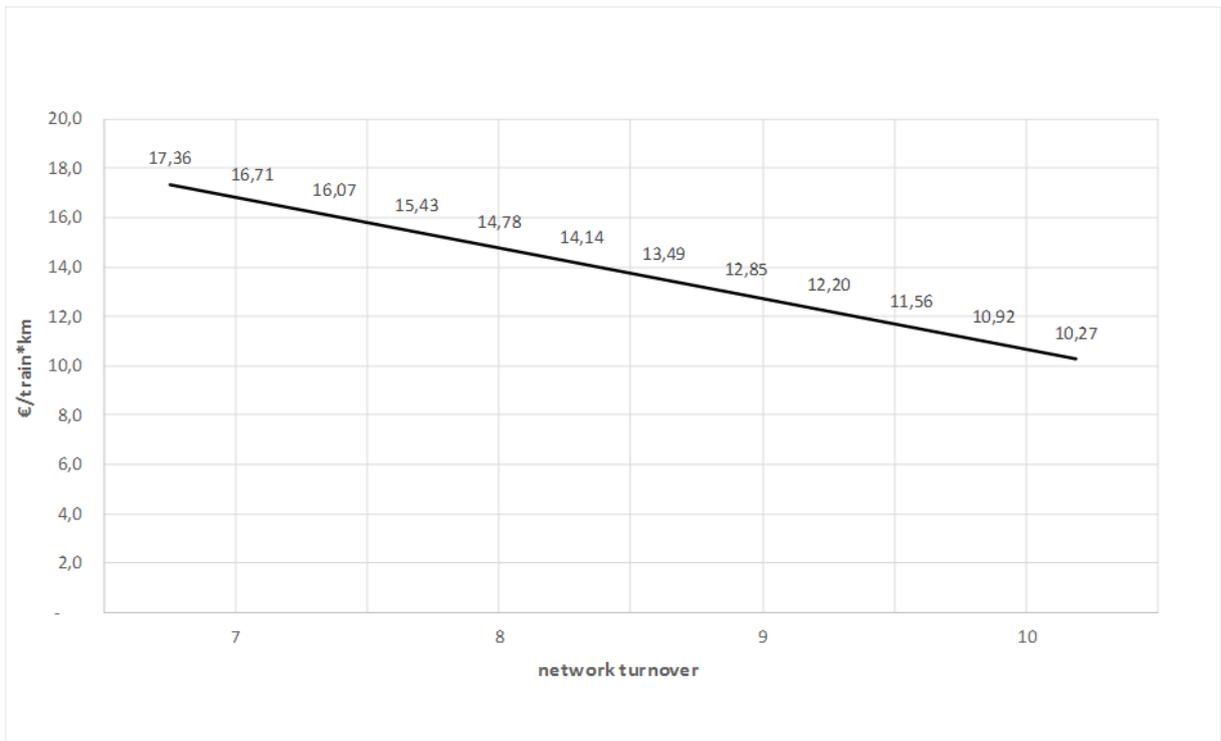


Figure 2. Example A: simulating the effect on  $Ctkm$  of an increase in the network turnover

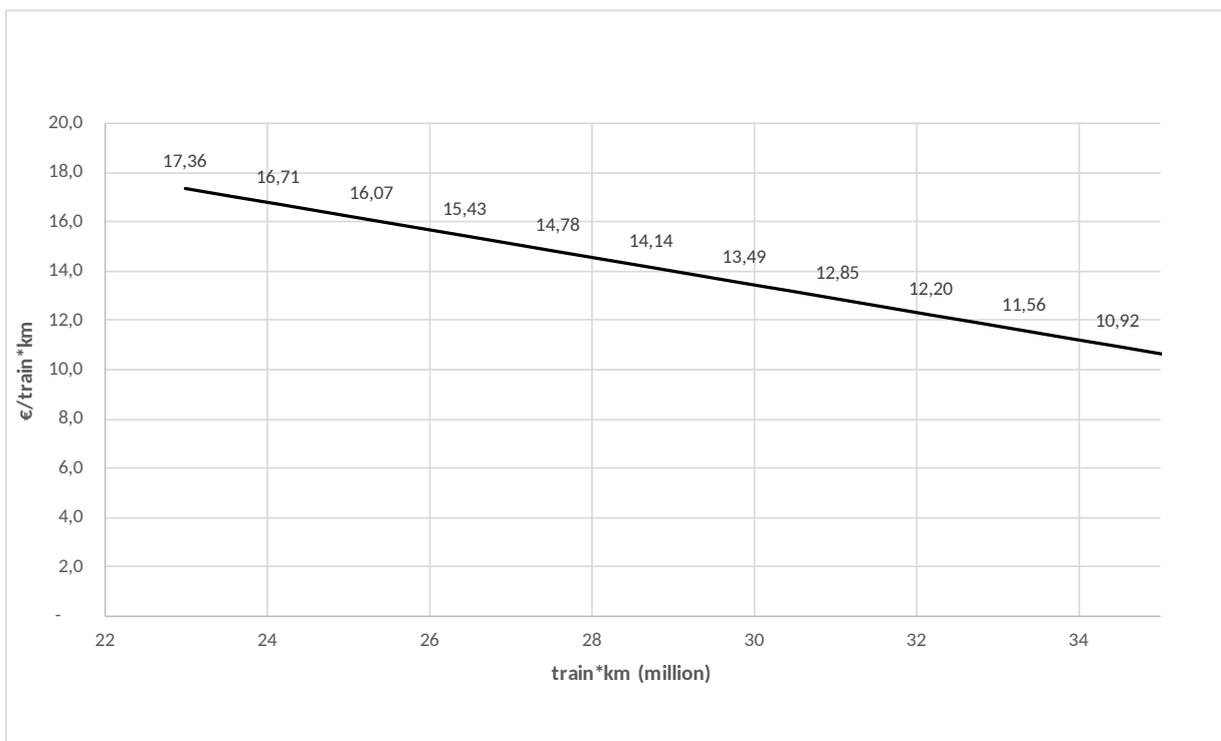


Figure 3. Example A: simulating the effect on  $Ctkm$  of an increase in the size of the service

Finally, to make it workable for regulatory purposes and pursue the efficiency goal in allotting public funds, the estimates provided by the econometric model could be modified by appropriate regulatory constraints. By doing so, we hybridize the proposed top down model by taking into account some aspects of process re-engineering.

For instance, the regulatory agency could link the maximum number of seats offered on average in each ride to the load factor detected during peak hours. In fact, the main driver in fleet sizing is the load factor at peak-time. Thus, should such a load factor be lower than a minimum acceptable threshold level (for example lower than 50%), then the regulatory agency could assign to the train company a unit standard cost corresponding to a downsized amount of seat kilometres in order to comply with a feasible load factor level. By doing so, the operator has an incentive to tailor the fleet to the existing demand level. In such a case, instead of assigning a unit cost based on the actual average number of seats per train, the regulator could acknowledge an unit cost based on a rolling stock characterized by a smaller number of seats per train.

For example, the average number of seats per ride may be reduced in such a way as to make the peak-load factor at least equal to 50%. The following formula exemplifies the rule to apply:

$$adjusted\ seats\ per\ ride = offered\ seats\ per\ ride \times \left( \frac{peak - load\ factor}{50\%} \right)$$

In such case, coming back to Example A, if the real peak-load factor was 38%, the downsized number of seats per train would result in  $\lceil 435 \times \frac{38}{50} \rceil = 331$ , and the number of seat kilometres would be reduced from 10,875 mln to 8,275 mln.

$$C_{skm} = 0.02716 \underbrace{\frac{+0.24975}{50-28}}_{\text{commercial speed effect}} - 0.00349 \underbrace{\times \frac{8,275}{1\ 600}}_{\text{network turnover effect}} + \underbrace{3.52342 \times 0.00577}_{\text{degree of renewal effect}} + 0 \times 0.02816 = 0.04079 \text{ € / srkm}$$

From the cost per seat kilometre we can easily calculate the cost per train kilometre:

$$C_{tkm} = 331 \times C_{skm} = 13.50 \text{ € / trkm}$$

Figure 4 depicts the effect of the peak-load factor-based correction rule on the standard cost per train kilometre of the service.

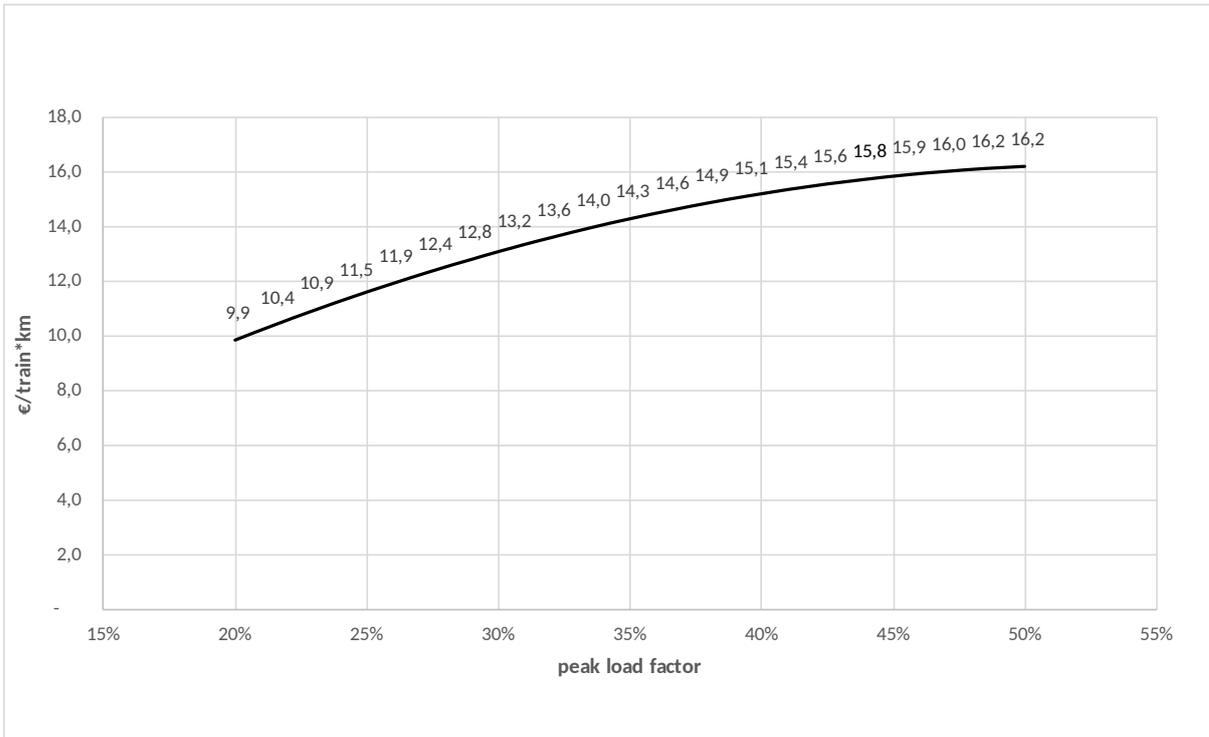


Figure 4. Example A: simulating the effect on  $Ctkm$  of an increase in the peak load factor

## 7. Concluding remarks

In this paper we proposed a workable top down econometric model to compute the economic standard cost of a regional public rail passenger transport service. The model has been defined assuming an efficiency framework that reflects the average performance of the observed LPTR operators. Because of the small number of observations and the heteroscedasticity of the sample, we employed wild bootstrap techniques to safeguard consistency of the estimated model.

The economic standard cost per seat kilometre of a regional public rail passenger transport service have been estimated by a multivariate regression model based on specific features of the produced service, namely, the commercial speed, the intensity of usage of the railway and the rolling stock renewal. In particular, this unit cost decreases as both the commercial speed and the intensity of usage raise, while it increases when the monetary value of the rolling stock grows.

We extended the model by setting minimum/maximum thresholds for some basic characteristics of the services at issue (a lower bound for the on-peak load factor and an upper bound on the fleet renewal degree). The model can be modified by introducing some regulatory constraint to mitigate the impact of particularly expensive and customized local services on the sharing the national public financial resources among the Italian Regions.

This paper responds to the changes occurring in the Italian transport policy in two ways. First, the proposed model represents a useful and extremely simple tool for the policy makers in the allocation of public funds amongst the Italian Regions. Second, the proposed unit standard cost model works also as a reference in determining the maximum economic

compensation allowed to rail operators both when services are tendered out and when they are in-house provided.

The proposed model identifies functional relationships between the unit cost of the service and crucial variables partially controlled by the rail operators (such as the commercial speed and the scale). In so doing, the model outcome provides Regions and the lower level local authorities with information about the impact of some policy decisions on the costs of the offered regional public rail transport services. For instance, a Local Authority that decides to increase the number of stations to improve the capillarity of the service is able to estimate the unit cost increment due to the resulting lower commercial speed. Similarly, a Local Authority that reduces the scale of a service may anticipate of the unit cost of service will rise.

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## Appendix

In this section we show how the average number of overall kilometres produced yearly by any train used for the rail service can be assessed in terms of commercial speed and rail turnover by using an OLS estimation. In particular, the proposed model to estimate the yearly train productivity  $TPy$  is as follows:

$$TPy = \alpha_2 + \beta_2 \times (Sp - 30) + \gamma_2 \times \ln(0.5 + T)$$

The model indicates that the impact of the commercial speed on the yearly train productivity is modelled through a linear shape, while a logarithmic function describes the rail turnover effect. Moreover, the constants of the regressors  $(Sp - 30)$  and  $\ln(0.5 + T)$  have been selected in order to maximize the fitness of the regression and the significance of the parameters.

Table 5 shows the results of the estimated model.

<i>Regressor</i>	<i>Coefficient</i>	<i>Estimates (std. err)</i>	p-value	Bootstrap p-value
Constant: 1	$\alpha_2$	22,675.78** (10,476.62)	0.039	0.046
Commercial speed: $Sp - 30$	$\beta_2$	1,632.32*** (353.08)	0.000	0.000
Network turnover: $\ln(0.5 + T)$	$\gamma_2$	34,253.84*** (6,340.66)	0.000	0.000
n. obs. = 29		Breusch-Pagan test for heteroskedasticity:		
F = 29.30		LM=2.051 p-value:0.358		
R <sup>2</sup> = 0.6926				

\*\*\*=Significant at 1% level; \*\*=Significant at 5% level; \*=Significant at 10% level, based on 9999 bootstrap replications.

**Table 5. Yearly train productivity: regression results**