Technology and incentive regulation in the Italian motorways industry*

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Abstract

Making use of an original dataset containing information on 20 Italian motorway concessionaires over the years 1992-2004, we study the technology prevailing in the motorways industry in Italy, with particular reference to the estimation of the technical progress for the years covered by our sample and to the measurement of the economies of scale and density. We find that the industry has experienced significant technical progress and shows sizeable economies of scale and density. These results provide valuable insights for regulatory purposes, notably for the optimal dimension of the network of a concessionaire and the correct setting of the X factor in the price cap formula, which is used to regulate the toll levels. We also control for the effects on the performance of the concessionaires due to the changes in the ownership structure and the regulatory regime, introduced by the recent reform of the industry. We find that the productivity of the concessionaires has not increased with the adoption of a price cap regime, while it has benefited from the privatisation process.

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1 Introduction

The motorways industry is probably "the last of Mohicans" amongst utilities in Europe. In spite of its very important contribution to the GDP (both directly, when roads are subject to payment, and indirectly, as part of a nation's transport infrastructure) and of its nature of industry characterised by natural monopoly conditions and heavily subject to regulatory intervention, it has, quite paradoxically, attracted little attention by regulation economists. Also, the great advances which have been observed in the last 20 years in the theory and practice of regulation of utilities have affected only marginally the regulatory practices adopted in this industry.

Institutional arrangements for the motorways industry show some similarities across European countries. The operation of motorways is awarded to concessionaires, usually within a multi-decennial contract; the concessionaires sometimes also build the motorways, which is returned to the State at the end of the concession period. Tolls are set to cover the concessionaires' costs. However, there is a great variability on many other aspects of the institutional and regulatory framework within EU member states; this variability relates to the ownership of the concessionaires, the size of each concessionaire's network, the way the operating and road construction expenditures of the concessionaires are financed, as well as the principles underlying the regulatory mechanism for toll updates. This heterogeneity is partly explained by the limited knowledge on how the different contractual and regulatory options affect the industry performance. The large differences in the size of concessionaires' networks, for instance, reflect the lack of formal empirical analysis on the optimal size of a motorway network. Similarly, the variety of ownership and toll regulation forms adopted in the industry go together with the absence of any investigation of the effects of the ownership structure and regulatory framework on the performance of the industry. Moreover, the specific measurement of the rate of technical progress displayed by the industry technology has never been attempted and, consequently, never used to determine the rate of adjustment of tolls.[1]

The aim of the present paper is to start filling these gaps. We do so by focusing our analysis on the Italian motorways industry: this is a national industry which is interesting for itself (relatively to EU15, it accounts for slightly less than 20% of the motorways network) but also whose history is such that its investigation can provide useful insights on the functioning of the motorways industry in general. In the first place, the motorways network is operated by several concessionaries of very different sizes: the number and the dimensional heterogeneity of the concessionaires makes the Italian motorways industry an ideal laboratory for investigation of the industry technology. Moreover, the regulatory reform of the industry undertaken in the 90's has lead to a widespread privatisation process and has provided for a switch of the regime of toll regulation, from cost-of-service to price cap regulation. These changes, clearly part of a more general redefinition of the role of the State in productive activities, elicit the issue of the nature of their effects (if any) on the productivity of the concessionaires and of the whole industry.

In our investigation, we make use of a unique dataset, covering the 1992-2004 period, which contains the concessionaires' financial indicators and institutional characteristics, and the features of the network under their operation. We estimate a total cost function with flexible functional form (translog), augmented with hedonic variables reflecting characteristics of the sections served, ownership and regulation dummy variables, and a temporal trend.

While there are several papers on other transport and utilities industries, there are relatively a few studying the technology of the motorways industry.[2] Our paper contributes to this literature by providing a measurement of the economies of scale and density, which in turn are used to assess the optimal size of a concession, and

[1] For a fuller account of the European motorways industry, see Ragazzi and Rothengatter, 2005.

[2] For a survey of technological studies on transport industries, see Braeutigam (1999). Most existing studies on the motorway industry have mainly focussed on the evaluation of the full cost of motorway transportation (Levinson and Gillen, 1999; U.S. Department of Transportation Federal Highway Administration,1997; Suter *et al.*, 2002), or some of its components (Link, 2006), mainly for the purposes of defining the optimal pricing structure.

an estimate of the technical progress occurred over the years covered by our dataset, which gives useful information for the rate of toll adjustment.[3] Our results show that a significant technical progress, which for the median firm is around 0.3% per year, has occurred in the industry. We also find that economies of scale are never exhausted for any size of the network covered by our sample, despite being relatively small for networks larger than 1,000 kms.

In our estimation, we also control for possible effects of the ownership and of the regulatory regime on the productivity of the concessionaires. The existing literature finds no systematic significant difference between public and private operators in terms of firm's productivity performance.[4] In contrast, we find private concessionaires to be more productive than the public ones, the former enjoying a cost advantage of around 3%. This may be probably explained by the well known inability shown in the past by Italian public institutions to run public enterprises efficiently.[5]

Also, our results show that the adoption of price cap regulation has not had any effect on the concessionaires' productivity. This goes in the opposite direction of the received *theoretical* literature which emphasizes the better incentives to technology acquisition and overall production efficiency that price cap regulation provides relatively to rate of return regulation.[6] Note, however, that our result fits well with the inconclusive evidence found by previous *empirical* research.[7] These results may be

[3] Under price cap regulation, the rate of toll adjustment is determined by the X factor. This is set to "embodie forecast of what productivity improvements can be achieved" (Beesley and Littlechild, 1989, p.461). For an analysis of the determination of the X factor under price cap regulation, see Bernstein and Sappington (1999) and the more general treatments by Armstrong *et al.* (1994), Armstrong and Sappington (2005) and Joskow (2007).

[4] See, for instance, Florio (2004) for evidence on the UK case and Nicoletti and Scarpetta (2003) on 18 OECD countries.

[5] See Bottasso and Sembenelli (2004) for evidence in the manufacturing industry.

[6] The classical reference here is Cabral and Riordan (1989); for further references, also with less clear-cut results, see Armstrong and Sappington (2005).

[7] Most of the received evidence refers to the US telecommunication industry. Shin and Ying (1993) and Resende (1999) find no effect of the regulatory regime on productivity (or efficiency) whereas incentive (price cap) regulation seems to have been found a positive effect by Tardiff and Taylor (1993), Majumdar (1997), and Resende (2000). Different samples and methodologies used by these papers might explain the inconsistent results. Also the local public transport industry has been investigated: Dalen and Gómez-Lobo (2003) and Piacenza (2006) find that incentive regulation has a positive effect on the efficiency of operators in Norway and in Italy respectively.

motivated by the difficulty in sorting out the effects of regulation from the effects of other contingent and institutional factors, a problem which seems to arise in our case as well. Specifically, the incentive power of price cap regulation for Italian motorways concessionaires may have been weakened by a quality adjustment featuring in the price cap formula, which has introduced elements of cost-plus regulation in the regulatory framework.

The paper is organized as follows. In Section 2 we briefly survey the history of Italian motorway industry. Section 3 presents our sample and the model we use to perform the empirical analysis, based on the estimation of a total cost function, and Section 4 discusses our regression results. In Section 5 we provide more economic interpretations and policy implications of those results. A data appendix concludes the paper.

2 A short history of the motorway industry in Italy

The motorways network in Italy extends (at end of June 2006) to 5,659 kms of tolled and 894 km of untolled roads. The network is currently operated by Anas, the State Department for road and motorways, and by 24 concessionaires. The object of the concession contracts is the maintenance of the network and the provision of motorways services; in some cases, the concession contract also provides for the construction or the enlargement of the motorway by the concessionaires. In all cases, the ownership of the network is retained by the State, to whom the concessionaire has to return the motorway at the end of the concession period.[8]

The majority of the motorways network was built between 1960 and 1975, and was largely financed by the State. Most of the currently existing concessions were awarded in those years, typically to publicly owned firms, and the relationship between these and the State was a textbook example of public enterprise economics. For publicly owned concessionaires, the State guaranteed the loans taken up by the concessionaires

[8] For a full account of the history of the industry, see Manzi (2001), Iozzi (2002), Benfratello *et al.* (2006).

to finance the construction of the motorway. Tolls were set to grant revenues sufficient to cover the concessionaires' costs; revenues and costs were evaluated on the basis of a financial plan, detailing all relevant revenue and cost items for the whole period of the concession, and which was agreed upon at the beginning of the concession period. Concessionaires were obliged to transfer to the State any profit in excess of a given threshold. Tolls were reviewed annually by a ministerial decree, which determined the rate of increase to be applied uniformly across concessionaires and vehicle classes. On several occasions, allowed increases were blocked for anti-inflationary purposes.

A radical reform of the Italian motorway industry was undertaken during the 90's. This, along the lines of the many similar reforms which took place in the same years in developed countries, had as the main objective the increase in the economic efficiency of the industry, by replacing government ownership by economic regulation. The reform therefore entailed the privatisation of the concessionaires and the creation of a regulatory framework more appropriate for the new ownership structure.

The privatisation programme went on speedily, and many concessionaires were privatised, with the most relevant transaction being the privatisation of Autostrade in 1999. Table A4 in the Data Appendix illustrates this process and shows that the number of privately owned concessionaires sharply increased from 1992 to 2004.[9]

The new regulatory framework was initially defined in 1996 (and later modified in 2004 and 2007) and came into force with the renegotiation of all the existing concession contracts, between 1997 and 2000. This new framework removes any discrimination across concessionaires based on their ownership (i.e. private or public) and introduces a form of incentive regulation, providing for toll levels to be determined to cover the concessionaires' expected cost, evaluated over the whole concession period: as before, revenues and costs are evaluated on the basis of a financial plan. Toll dynamic is regulated through a price cap formula, whose parameters are to be

[9] This trend is obtained both if we define a privately owned firm as a firm whose largest shareholder is a private investor and if we use an alternative definition according to which a privately owned firm is a firm whose private shareholders control more than 50% of its shares. Although figures in Table A4 only refer only to the set of concessionaires we use for estimation, they illustrate well the trend occurred in the whole industry.

revised at fixed intervals. The price cap limits the increases of a Laspeyres index of tolls – now determined by the concessionaries – to the rate of inflation, adjusted for expected productivity gains and changes in the quality of services provided. That is,

$$\left[\frac{\sum_i p_i^t q_i^{t-1}}{\sum_i p_i^{t-1} q_i^{t-1}} - 1\right] \times 100 \leq \Delta RPI - X + \beta \Delta Q + K \tag{1}$$

where p_i^t and p_i^{t-1} are the (per km) toll paid by a vehicle of type i in year t and $t-1$ respectively, and q_i^{t-1} are the total kms travelled by vehicles of type i in year $t-1$. Also, ΔRPI is the change in the Retail Price Index and X is the offset productivity factor. The $\beta \Delta Q$ term is the change in a composite quality index Q, multiplied by a scaling factor β. Finally, K is calculated to ensure an increase in tariffs generating revenues to cover the previous year's investment expenditures.[10]

While the rest of the (1) is a standard example of a Laspeyres-type price cap, the adoption of a quality component in the price cap formula is quite an unusual feature (at least, at the time of its introduction) and, for reasons which will be clear later in the paper, deserves a more detailed treatment. In general, the quality correction term in the price cap formula creates a link between the quality provided by the firm and its allowed prices, inducing a form of market response by the firm, which can "sell' higher quality to consumers.[11] As to the specific functioning of the quality correction in (1), the quality index Q is solely based on the number of accidents on the network and the roughness of the road surface. The β factor varies with the initial level of quality: when quality increases (decreases, respectively), takes on larger (smaller) absolute values the higher is the starting level of quality. Therefore, the allowed increase in prices due to the higher quality seems to be related more to the costs borne by the firm because of the higher quality (typically increasing with the quality level at an *increasing* rate) than to the benefits accruing to the consumers (increasing

[10] The K factor was introduced in the price cap formula in 2007, when also the X factor was defined as the factor which equate (expected) revenues to (expected) cost for the next 5-year regulatory period.

[11] For a theoretical treatment of this issue, see De Fraja and Iozzi (2004) and the survey by Sappington (2005).

at a *decreasing* rate with the quality level).

3 Sample, model, and estimation technique

3.1 The sample

We use a unique dataset containing information over the 1992-2004 period for 20 Italian motorway concessionaires.[12] Data were retrieved via inspection of several sources, such as official reports, publications from AISCAT (the concessionaires' association), and other sources (mainly press articles). The database contains firms' financial indicators (such as costs, revenues, inputs), characteristics of the sections served (such as length, number of stoneworks, percentage of network with three bands, total number of kms travelled) and concessionaires' institutional characteristics (such as ownership - private vs. public - and the type of regulation - price cap vs. rate of return).

Figures from 1 to 3 and Table A2 in the Data Appendix depict the industry and its evolution in recent years.[13] The main features emerging from our data are the following. Firstly, the Italian motorway industry is composed of one huge concessionaires ("Autostrade per l'Italia") controlling almost half of the whole network and a host of relatively small concessionaires: the differences between mean and median values of the last two rows of Table A2 highlights this asymmetry. Secondly, a constant upward trend in total kms travelled is recorded, the average yearly growth rate being approximately 3.2%. Finally, since 1999, a sharp increase in profit before tax and in maintenance costs is found, whereas a slight decrease in labour costs has occurred all over the period. We defer the interpretation of these observations to the last section, in order to relate them with our econometric results.

[12] Our sample virtually represents the whole industry, composed in 2005 by 24 concessionaires. Our sample excludes 2 concessionaires which operate only tunnels and 2 concessionaries which started operations in 2003. For further details on this and on the other features of our data set, see the Data Appendix.

[13] Figures 2 and 3 report median and not average values as the latter are highly affected by the size of "Autostrade per l'Italia" which is much larger than the other concessionaires. Costs and profits have been deflated with the consumer price index to allow comparability over time.

3.2 The model and the estimation technique

We estimate a total cost function with three inputs (labour, maintenance, and other inputs), one output (the number of kms travelled), and a variable representing the network length. We also add neutral technical progress, some hedonic (control) variables reflecting the characteristics of the network and, most importantly for the purposes of this paper, ownership and regulation dummies. The most general model we estimate is the following translog specification:

$$\begin{aligned}
\ln TC = {} & \beta_0 + \beta_o \ln p_o + \beta_l \ln p_l + \beta_m \ln p_m + \\
& + \frac{1}{2}\beta_{oo}(\ln p_o)^2 + \frac{1}{2}\beta_{ll}(\ln p_l)^2 + \frac{1}{2}\beta_{mm}(\ln p_m)^2 + \\
& + \beta_{ol} \ln p_o \ln p_l + \beta_{ml} \ln p_m \ln p_l + \beta_{om} \ln p_o \ln p_m + \\
& + \beta_y \ln y + \beta_{yy} \ln y^2 + \beta_{oy} \ln p_o \ln y + \beta_{ly} \ln p_l \ln y + \beta_{my} \ln p_m \ln y + \\
& + \beta_n \ln n + \beta_{nn} \ln n^2 + \beta_{on} \ln n \ln p_o + \beta_{ln} \ln p_l \ln n + \beta_{mn} \ln p_m \ln n + \\
& + \beta_{yn} \ln y \ln n + \beta_t t + \beta_{own} own + \beta_{reg} reg + \beta_{st} stone + \beta_{3d} 3band + \varepsilon \qquad (2)
\end{aligned}$$

where TC is the total operating cost; p_m, p_o, and p_l are prices for maintenance, other inputs, and labour respectively. y is the total number of kilometers travelled, n is the network length. t is a time trend (i.e. $t = 1$ when the observation year is 1992 and $t = 13$ when the observation year is 2004). own and reg are two time variant dummy variables: the former indicates whether the concessionaire is under private or public ownership (1 for private, 0 for public) whereas the latter takes on a value of 1 if the firm is under price cap regulation and 0 if it is under a rate-of-return regime. $stone$ is the number of stoneworks standardised for the length of the network, and $3band$ is the percentage of the network with three bands. All variables are indexed i, t with $i = 1, \ldots, 20$ and $t = 1992, \ldots, 2004$.

We estimate a system of equations composed by equation (2) and the corresponding cost shares (derived via the Shephard's lemma) by using the SUR technique.[14] As

[14] The software we use is Stata, version 9.2.

usual, to avoid singularity of the variance matrix of the errors, we drop one cost share (the one for other inputs). We impose the usual restrictions stemming from homogeneity of degree 1 in prices of the cost function and from cross equations symmetry (for further details, see Greene, 2003: pp. 367-368).

Furthermore, in order to ease the computation of elasticities, we standardise all prices, the network variable, kms travelled, and total cost by their value evaluated at some relevant percentile (such as the median) so that first order coefficients are the elasticities evaluated at that percentile.

To control for individual heterogeneity, we add to the total cost function equation (2) individual (concessionaires) dummies, in order to capture time invariant unobserved heterogeneity which might be correlated with included regressors. We label the models with individual dummies among regressors as fixed effects (FE, henceforth) models. However, it is well known that inclusion of individual dummies prevents the estimation of time invariant regressors and hampers precise estimation of regressors almost invariant, which is our case for most network characteristics, in particular network length. To improve the accuracy of our technological results, in particular the measurement of scale economies, which heavily relies on network characteristics, in some models we drop individual dummies from the total cost function equation. Finally, as the translog results might be dominated by second order and interaction terms, we also estimate as a robustness check a restricted version of the system corresponding to a Cobb-Douglas cost function and two constant shares.

4 Regression results

In this Section we present our estimation results. In particular, we estimate the parameters of the sector's underlying technology which, to the best of our knowledge, have never been obtained so far for the motorway industry, neither in Italy nor in other countries. By adding dummy variables representing ownership structure and regulation regime, we also control for the effects of these variables on the concessionaires' productivity.

As for the technology in the industry, a first measure we obtain is *scale elasticity* (Caves *et al.*, 1984), given by

$$\varepsilon_s = \frac{1}{\varepsilon_y + \varepsilon_n}, \tag{3}$$

where ε_y and ε_n are the elasticity of total cost with respect to output (kilometers travelled) and to network length respectively. Therefore, ε_s measures the inverse of the percentage increase in total cost due to a percentage increase in output *and* in the network length. A value above (below, respectively) 1 indicates increasing (decreasing) returns to scale.

A second measure is *density elasticity* (Caves *et al.*, 1984), defined as

$$\varepsilon_d = \frac{1}{\varepsilon_y}; \tag{4}$$

this measures the inverse of the percentage increase in total cost due to a percentage increase in output, holding the network length fixed. A value above (below) 1, showing increasing (decreasing) returns to density, indicates that the network is underexploited, so that an increase in output induces a less-than-proportional increase in total costs.

The last important measure illustrating the characteristics of the underlying technology is the yearly rate of technical progress, measured by

$$\varepsilon_t = \frac{\partial \ln TC}{\partial t}; \tag{5}$$

a negative (positive) value of (5) shows technical progress (regress).

Insert Table 1 about here

Table 1 presents our main results: columns (1), (3), and (6) show those of the fixed effects (FE) models, whereas all other columns contain the estimates of models without individual dummies.

In columns (1) and (2) estimates of our basic model are presented. Both specifications do not include ownership and regulation dummies and, as already mentioned above, differ for the inclusion of concessionaires' individual dummies in column (1). Results in the two columns are quite similar. Coefficients of prices are positive, almost identical across the two models and highly significant. As we standardise all the regressors with their medians, first order coefficients represent elasticities evaluated at the sample medians. Technogical progress is in the order of $0.3\% - 0.5\%$ *per annum*. This is probably due to the introduction of automatic toll systems, and should be read in combination with the small reduction in labour expenses outlined in Section 3.1.

The coefficients for network length and total number of kms travelled have in both models the expected sign and are highly significant. However, while the latter are quite similar across models, the former differ quite sensibly. As a result, the degree of density economies is quite consistent across models and shows that, on average, the Italian motorway network is underexploited. On the other hand, scale economies differ between the two models: when fixed effects are included, scale economies are 0.86 (standard error 0.06) whereas they are 1.11 (standard error 0.01) when fixed effects are omitted. The differences in the network coefficients and, consequently, on the degree of scale economies observed in the two models might be explained by the time pattern of the network variable, which is slowly time variant and enters the specification not only linearly but also as second order terms, thereby inducing high variability in the estimates. As a consequence, we argue that the estimate of this variable coefficient obtained with the FE model must be taken with caution and concentrate our comments on the one obtained with the model without individual dummies. Indeed, results in column (2) suggest that an increase in concessionaires' size might reduce average cost. Notice that the individual dummies are jointly significant, highlighting concessionaires' heterogeneity.

We include ownership and regulation dummies in columns (3) and (4), for the FE model and the one without individual dummies, respectively. The introduction of these new variables leaves the price coefficients almost unchanged; also, the networks and output coefficient are very similar relative to the previous models, with the minor exceptions that technological progress in the FE models is slightly less pronounced than before. As to the new variables, in the FE model firms under private ownership prove to be more productive than public concessionaires, the ownership dummy being negative and very significant, and showing that private firms enjoy a cost advantage of approximately 3% with respect to public ones.[15] Conversely, in the model without individual dummies, the coefficient of the ownership dummy is different not only in the magnitude but also in the sign, highlighting that omitted variable bias due to unobserved heterogeneity correlated with regressors is at work. In particular, some characteristics of the network affecting costs could be positively correlated with the ownership dummies. Instead, the two specifications do not differ as to the effects of the introduction of a price cap regime: this event does not seem to affect firms productivity as the regulation dummy is not significant at any reasonable statistical level.

In column (5) we try to model unobserved heterogeneity by including two variables capturing two characteristics of the network: the percentage of three bands network and the number of stoneworks standardised for the network length. Notice that these characteristics are (almost) time invariant so that fixed effects cannot be included. Results show that the number of stoneworks positively and significantly affects costs, whereas network composition (in terms of number of bands) does not seem to affect costs. Notice that now the coefficient of the ownership dummy is not significant and less pronounced, showing that network characteristics partially explain the apparent cost disadvantage of private firms found in model (4).

Finally, in columns (6) and (7) we check whether our results could be driven by squares and interaction terms, i.e. points far apart from the sample median. As

[15]In our models the ownership dummy takes a value of 1 if the concessionaire is under the *control* of private firms or individuals. We check the robustness of our results by using an alternative ownership dummy taking a value of 1 if the *largest shareholder* is a private firm or an individual. Results are very similar to those presented in the text and are available from the authors upon request.

expected, results of the specification without individual dummies (column 7) prove to be quite similar to those obtained with the other models (e.g. columns (2), (4), and (5)), the only remarkable differences being a less significant technical progress and a significant (and negative) ownership dummy. On the contrary, results in column (6), the specification with fixed effects, do differ from those in columns (1) and (3). In particular, not only the coefficient of the ownership dummy is almost twice as much as before (7%), but also density and scale elasticities are much higher than before, the former being 1.52 and the latter 3.19. The latter finding provides further evidence that the technological results obtained with fixed effects must be taken with caution.

To explore the issue of scale and density elasticities further, we evaluated these measures at sample points different from the median. In doing so, we rely only on the specification without individual dummies and include ownership and regulation dummies (i.e. the model presented in column (4) in Table 1), and we keep on evaluating prices at their median. Results are summarised in Table 2.[16]

Insert Table 2 about here

Technology exhibits increasing returns to scale (the scale elasticity being of the order of 1.13) for sample points corresponding to the 10^{th} percentile of the network and kms travelled distributions. This point corresponds with very small concessionaires, serving less than 40 kms. Evaluating scale elasticity at increasingly higher percentiles, returns to scale decrease quite slowly, so that at the 90^{th} percentile the scale elasticity is 1.09. In the light of the huge dimension of one concessionaire serving almost half of the Italian network, we also evaluated scale elasticity also at point corresponding to multiples (5, 10, and 15 times) of the the median of network and kms travelled. We find that even for a network of almost $2,000$ kms, economies of scale are not exhausted. As for density elasticity, the value ranges from 2.12 to 1.68,

[16] The results are virtually unaffected if we use one of the other models without individual effects of Table 1. Results are available from the authors upon request.

so that the Italian network seems to be underexploited, no matter the evaluation point.

5 Concluding remarks

This paper is the first to provide empirical evidence on the technology prevailing in the motorways industry in Italy, providing useful information for the design of motorways concessions and for the definition of "good' regulatory policies. As it might be argued that a similar technology is adopted by concessionaires in other countries, the relevance of our results are not confined to the case of Italy. We perform our analysis using a unique dataset containing information over the 1992-2004 period for a sample of Italian motorways concessionaires, which virtually represents the whole national industry. This dataset allows us to estimate a total cost function with flexible functional form (translog), augmented with hedonic variables reflecting characteristics of the motorway sections served, ownership and regulation dummy variables, and a temporal trend.

Our analysis shows that the technology adopted in the industry exhibits scale economies for any size of the network we could reasonably investigate with our dataset. As a matter of fact, we find that an equiproportional increase in traffic and network size causes a less than proportional increase in costs even for a concessionaire controlling a network as big as 2,000 kms. In terms of policy implications, this is a result of general interest for the determination of the optimal size of motorways concessions. Applied to the Italian case, it points out the inefficiency of the existent large heterogeneity in the size of the networks controlled by concessionaires (from over 2,000 kms of the largest concessionaire to only 40 kms of the smallest one); moreover, this result suggests the need of aggregation between concessionaires and the opportunity of awarding to existing firms any new concessions for the operation of networks of limited size.

We also find that the technology exhibits relatively large density economies, no matter the size of the network or the volume of traffic. By implying that an increase in traffic, holding the network constant, increases costs less than proportionally, this result suggests that the Italian motorways network is underexploited, at least on average terms, and induces some caution in evaluating the need of further network expansion.

Finally, our analysis shows that, over the years covered by our sample, the productivity of the concessionaires has slowly but steadily increased. The result provides a general and useful indication of the evolution of the technology also for other countries. Notice that, however, the increase in productivity we find is only partly motivated by technological progress, mainly introduced in the form of new technologies for toll payments. Another reason of the increase in productivity is the volume of traffic: because of the density economies, the sharp increase in motorways traffic observed in the last 10 years has caused a less than proportional increase in costs.

In recovering our technology parameters, we control for possible effects of the regulatory reform undertaken in this industry in Italy in the 90's on the productivity of the concessionaires. Privately owned concessionaires are found to have a significant cost advantage over publicly owned. This is somewhat contrasting with the prevailing results previously obtained in the literature on the regulation of public utility, which mostly finds an insignificant effect of ownership on productivity. This discrepancy is might be due to some peculiarity of the industry or, more in general, of the country. Indeed, we posit that this result is driven by the well known inefficiency of firms under the control of Italian public institutions in the years covered by our analysis. On the other hand, we find that the adoption in the Italian motorway industry of a price cap mechanism (which has followed a period of rate of return regulation) has not had any effect on the productivity of the concessionaires. Despite some important theoretical results illustrate the greater incentives for efficiency under price cap regulation, other empirical studies have found results in line with ours, namely no significant effect of the type of regulation on productivity. Similarly as in these latter investigations, we argue that this inconclusive result is due to the impossibility of disentangling the effects on efficiency of the type of regulation from the effects deriving from other specific provisions, which may weaken the positive effects on efficiency of incentive regulation. In our case, we specifically find the culprit in the quality adjustment contained in the price cap formula which provides limitless incentives to maintenance expenditures. Indeed, as it is illustrated at the end of Section 2, the quality adjustment term rewards with higher tolls any increase in the composite index of the quality of the services. For any given increase of this quality index, the allowed increase in prices does not depend on the starting level of the index and, paradoxically, is greater when the quality index is already high. Provided that the reward is high enough (as it seems to have been the case), it is then clear the incentive to the concessionaire to increase the quality of the services provided, irrespective to its cost and to any consideration over a socially optimal level of quality. Since one of the most relevant dimensions captured by the quality index is the roughness of the surface, it then comes as no surprise the sharp increase in maintenance costs observed after the introduction of price cap regulation (observable in Figure 3), in the light of the fact that the largest part of the maintenance costs is indeed due to the resurfacing of the road. Thus, this "premium' on maintenance costs - via the quality index in the price cap - might well have counterbalanced the overall incentive to efficiency from the regulatory setting.

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6 Appendix

6.1 Tables

Table 1: regression results, translog and Cobb-Douglas specifications, SUR estimates

Variable	*Parameter*	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Constant	β_0	0.12 (0.04)	0.05 (0.00)	0.11 (0.07)	0.05 (0.00)	0.04 (0.00)	−0.06 (0.63)	0.16 (0.03)
log price other	β_o	0.31 (0.00)	0.30 (0.00)	0.31 (0.00)	0.30 (0.00)	0.30 (0.00)	0.31 (0.00)	0.31 (0.00)
log price labour	β_l	0.41 (0.00)	0.41 (0.00)	0.41 (0.00)	0.41 (0.00)	0.41 (0.00)	0.43 (0.00)	0.41 (0.00)
log price maintenance	β_m	0.29 (0.00)	0.29 (0.00)	0.29 (0.00)	0.29 (0.00)	0.29 (0.00)	0.26 (0.00)	0.28 (0.00)
log kms travelled	β_y	0.56 (0.00)	0.52 (0.00)	0.52 (0.00)	0.52 (0.00)	0.53 (0.00)	0.31 (0.00)	0.51 (0.00)
log network	β_n	0.61 (0.00)	0.38 (0.00)	0.57 (0.00)	0.38 (0.00)	0.38 (0.00)	0.34 (0.00)	0.39 (0.00)
Time trend	β_t	−0.005 (0.00)	−0.003 (0.00)	−0.002 (0.02)	−0.003 (0.00)	−0.003 (0.00)	−0.001 (0.59)	−0.003 (0.41)
Ownership dummy	β_{own}	...	...	−0.03 (0.00)	0.008 (0.08)	0.006 (0.24)	−0.07 (0.00)	−0.04 (0.04)
Regulation dummy	β_{reg}	...	...	0.00 (0.43)	0.00 (0.98)	0.00 (0.87)	−0.01 (0.41)	−0.01 (0.70)
log price other^2	β_{oo}	0.20 (0.00)	0.20 (0.00)	0.20 (0.00)	0.20 (0.00)	0.20 (0.00)	...	...
log price labour^2	β_{ll}	0.21 (0.00)	0.20 (0.00)	0.21 (0.00)	0.20 (0.00)	0.20 (0.00)	...	...
log price maintenance^2	β_{mm}	0.18 (0.00)	0.16 (0.00)	0.18 (0.00)	0.16 (0.00)	0.16 (0.00)	...	...
log price lab.×log price other	β_{ol}	−0.12 (0.00)	−0.12 (0.00)	−0.12 (0.00)	−0.12 (0.00)	−0.12 (0.00)	...	...
log price lab.×log price maint.	β_{lm}	−0.09 (0.00)	−0.08 (0.00)	−0.09 (0.00)	−0.08 (0.00)	−0.08 (0.00)	...	...
log price maint.×log price other	β_{mo}	−0.08 (0.00)	−0.08 (0.00)	−0.08 (0.00)	−0.08 (0.00)	−0.08 (0.00)	...	...
log kms travelled^2	β_{yy}	0.24 (0.00)	0.23 (0.00)	0.21 (0.00)	0.23 (0.00)	0.23 (0.00)	...	...
log price other×log kms trav.	β_{oy}	−0.16 (0.00)	−0.15 (0.00)	−0.16 (0.00)	−0.15 (0.00)	−0.15 (0.00)	...	...
log price lab.×log kms trav.	β_{ly}	0.05 (0.00)	0.04 (0.00)	0.05 (0.00)	0.04 (0.00)	0.04 (0.00)	...	...
log price maint.×log kms trav.	β_{my}	0.11 (0.00)	0.12 (0.00)	0.11 (0.00)	0.12 (0.00)	0.12 (0.00)	...	...
log network^2	β_{nn}	0.63 (0.00)	0.30 (0.00)	0.50 (0.00)	0.30 (0.00)	0.28 (0.00)	...	...
log price other×log network	β_{on}	0.20 (0.00)	0.19 (0.00)	0.20 (0.00)	0.19 (0.00)	0.19 (0.00)	...	...
log price lab.×log network	β_{ln}	−0.12 (0.00)	−0.09 (0.00)	−0.12 (0.00)	−0.09 (0.00)	−0.09 (0.00)	...	...
log price maint.×log network	β_{mn}	−0.09 (0.00)	−0.09 (0.00)	−0.09 (0.00)	−0.09 (0.00)	−0.09 (0.00)	...	...
log kms trav.×log network	β_{yn}	−0.32 (0.00)	−0.25 (0.00)	−0.27 (0.00)	−0.25 (0.00)	−0.25 (0.00)	...	...
Stoneworks	β_{sw}	...	...	...	...	0.02 (0.02)	...	...
3bands network (%)	β_{3b}	...	...	...	...	−0.00 (0.56)	...	...
ε_d		1.79 [0.08]	1.93 [0.03]	1.94 [0.09]	1.93 [0.03]	1.89 [0.03]	3.19 [0.38]	1.98 [0.05]
ε_s		0.86 [0.06]	1.11 [0.01]	0.92 [0.07]	1.11 [0.01]	1.11 [0.01]	1.52 [0.25]	1.12 [0.01]
Firms dummies		(0.00)	...	(0.00)	...	...	(0.00)	...

Note: Firm level fixed effects are included in columns (1), (3), and (6). ε_d is the measure of density elasticity and ε_s is the measure of scale elasticity. P-values of the null that each coefficient (the set of coefficients) is (are) equal to 0 in round brackets. Standard errors in square brackets. The number of observations is 253 in all columns.

Table 2: Values of scale and density elasticities, translog specification, SUR estimates

	Estimation point		*scale elasticity*	*density elasticity*
	km travelled	*network*		
10^{th} p.	241.12	$36,6$	1.13 [0.01]	2.23 [0.06]
25^{th} p.	661.46	51.6	1.14 [0.01]	1.68 [0.03]
50^{th} p.	$1,270.03$	127.0	1.11 [0.01]	1.93 [0.03]
75^{th} p.	$1,921.36$	165.5	1.11 [0.01]	1.83 [0.03]
90^{th} p.	$3,864.67$	314.0	1.09 [0.01]	1.83 [0.04]
5 times	$6,350.15$	635	1.07 [0.01]	2.06 [0.06]
10 times	$12,700.30$	$1,270$	1.05 [0.01]	2.12 [0.07]
15 times	$19,050.45$	$1,905$	1.05 [0.01]	2.16 [0.08]

Note: Elasticities are computed using the specification in column (4) of Table 1. In the first five rows the evalutation points are percentiles of the kms travelled and network distributions. In the last three rows the evaluation points are multiples (5, 10, and 15 times) of the median of the kms travelled and the network distributions. Kms travelled is in million of kms and network is in kms. Standard errors in square brackets.

6.2 Figures

Fig. 1 Kilometres travelled over the entire network (yearly total, 1994-2004)

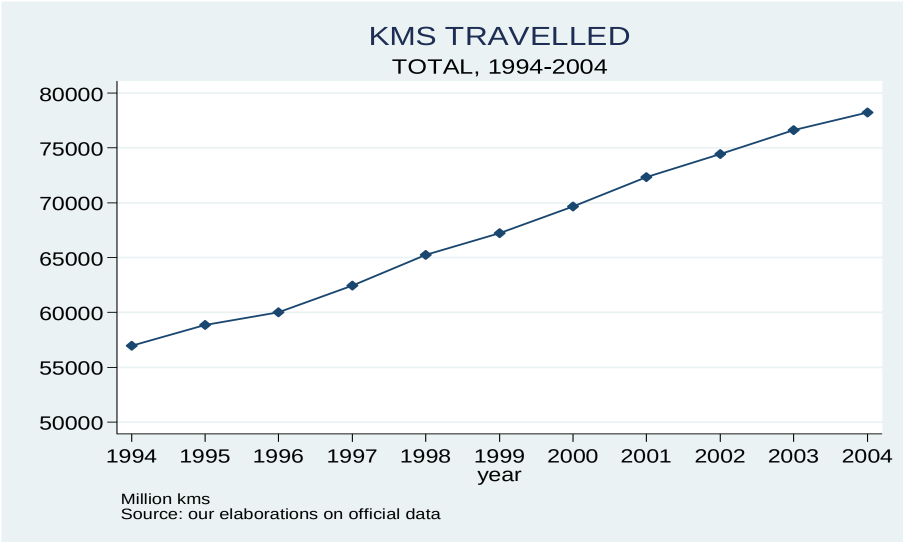


Fig. 2 Concessionaires' profits before tax (yearly median, 1994-2004)

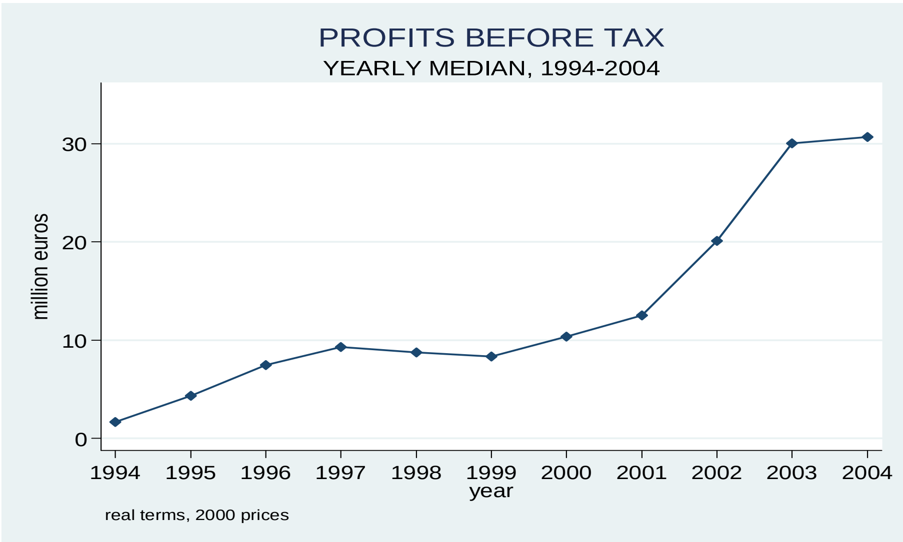
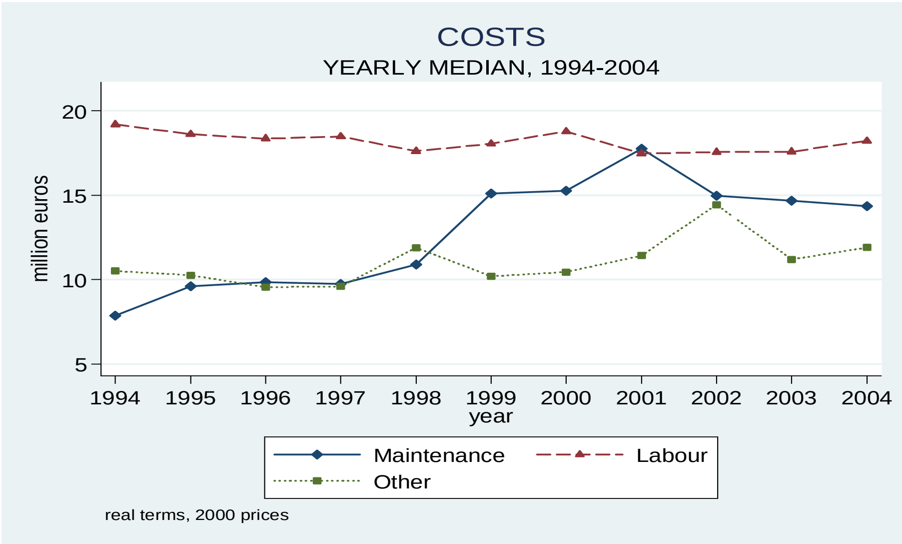


Fig. 3 Concessionaires' costs (yearly median, 1994-2004)


COSTS
YEARLY MEDIAN, 1994-2004
million euros
20
15
10
5
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
year
Maintenance
Labour
Other
real terms, 2000 prices

6.3 Data appendix

This appendix describes the data sources and illustrates how some of the variables have been computed. It also presents some descriptive statistics.

Our database contains information on 20 Italian concessionaires which virtually represent the entire motorways industry in Italy. Indeed, only four our concessionaires are excluded from our sample: two of them run only tunnel sections (Gran San Bernardo and Monte Bianco) and the other two started operations in 2003 (Strada dei Parchi and Consorzio delle Autostrade Siciliane). We collected our balance sheet data mainly through direct inspection of concessionaires' official statements. We retrieved information on the number of kilometres travelled, on some characteristics of the network (such as the number of stone works) as well as the number of accidents from the AISCAT (concessionaires' association) official reports. We retrieved information on ownership mainly from concessionaires' official reports, integrating when needed with the R&S directory, yearly published by the Mediobanca investment bank, and with the information provided by concessionaires' web sites. Information on the type of regulation have been collected by inspecting concessionaires' official reports.

Our sample is unbalanced as 7 observations are missing (see Table A1), because three concessionaires started operations in 1993 or 1994 and two of them merged in 2004. To avoid disomogeneity, we did not include the merged entity in the sample we use for estimation or descriptive statistics but only for Figures 1-3.

Table A1: Structure of the panel

	Frequency	PeriodObserved
	15	1992-2004
	2	1994-2004
	1	1993-2004
	2	1992-2003
Total concessionaires	20	
Total observations	253	

The variables used in the empirical analysis are described below and summarised in Table A2. Maintenance and labour costs are taken from the corresponding heading of concessionaires official statements (or from the auditors' notes) whereas other costs is the sum of materials, services (different from maintenance) and other operating variable costs, including depreciations. Maintenance (resp. other inputs, labour) price has been constructed by dividing maintenance (resp. other, labour) costs by the number of kms travelled (resp. network length, average number of employees). The number of stone works is the number of bridges and tunnels longer than 100 meters, divided by the network length.

Table A2. Descriptive statistics

Variable	mean	st. dev.	min	25^{th}	median	75^{th}	max
Costs							
maintenance	25.32	52.05	0.16	5.28	10.38	19.65	317.30
labour	33.89	71.47	3.33	10.19	16.91	24.29	357.77
other	25.06	68.89	2.21	6.21	10.06	18.29	796.44
profits	34.63	103.71	-17.55	1.51	8.85	27.56	911.04
Prices							
maintenance	11.65	11.52	1.29	5.90	8.93	13.11	102.42
labour	44.39	5.14	30.96	40.57	44.13	47.88	61.23
other costs	132.94	103.05	24.95	64.42	99.21	170.13	638.56
Other variables							
Kms travelled	3,345.76	8,523.14	32.00	661.46	1,270.03	1,921.36	46,733.12
network	256.55	607.25	20.00	51.60	127.00	165.50	2,854.60
stoneworks	0.41	0.35	0.03	0.09	0.32	0.61	1.40
3band network	23.75	34.31	0	0	0	47.61	100.00

Note: Costs are million Euros, prices are thousand Euros, both current prices. Number of kms travelled is in million kms and network is in kms. Stoneworks is the number of stone works divided by the network length and 3band network is in percentage of total network. All figures refer to the sample of 253 observations used in estimation.

Regulation regime is indicated by a time-variant dummy variable which takes a value of 1 if at the end of fiscal year the concessionaire is under a price cap (PC) regime (0 if rate of return). Most of concessionaires have been regulated under ROR until 2000, as shown in the following table.

Table A3: Changes in the regulatory regime (from ROR to PC), by year

Year	1998	2000	2001	2002	2003	Total
Frequency	1	15	1	1	2	20

Note: Absolute frequencies

Finally, we construct two time-variant firm specific dummies for ownership. The first dummy takes a value of 1 (0 otherwise) if the largest shareholder is a private firm or individuals for at least six months in the fiscal year; the second one takes a value of 1 (0 otherwise) if the majority of shares belongs to a private firm or individuals for at least six months in the fiscal year. Table A4 describes the distribution over time of these two dummies, and shows the effects of the privatisation process occurred in the 1992-2004 period.

Table A4: Public and private ownership, by year

Year	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
definition I													
Private	5	5	6	7	7	7	7	7	13	14	14	14	12
Public	12	13	14	13	13	13	13	13	7	6	6	6	6
definition II													
Private	1	1	3	5	5	5	6	6	12	12	12	13	11
Public	16	17	17	15	15	15	14	14	8	8	8	7	7
Total	17	18	20	20	20	20	20	20	20	20	20	20	18

Note: Absolute frequencies. Under definition I a concessionaire is defined as private if the largest shareholder is a private; Under definition II a concessionaire is defined as private if the majority of stakes belongs to private firms.