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Costs and efficiency of highway concessionaires: a survey of Italian operators

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Abstract

Measuring the productivity of highway concessionaires is very relevant, especially when a price cap regulation is applied where tariff increases are based on expected improvements of productivity. Output may be measured in terms of traffic or network length, or a combination of both, while quality of service should ideally be accounted for. To measure productivity we consider only operating costs, as amortization and financial costs depend upon the original highway design and historical costs. A cross section analysis of the Italian concessionaires shows that: 1) operating costs depend on both traffic and capacity; 2) economies of scale are relevant but their estimate is very sensitive to the model specification; 3) there are large differences in efficiency among operators, indicating that there could be significant room for yardstick competition.

We subsequently consider the main economic data regarding the major Italian concessionaire (Autostrade spa) over two decades. Revenues increased greatly, even more than traffic, while operating costs remained substantially stable in real terms, as the automation of toll collection allowed the company to reduce the number of collectors by almost half. Finally, a comparison between Italian and French concessionaires shows that the latter have much lower operating costs, which cannot be entirely explained by economies of scale or lower personnel costs.

Keywords: Highway; Regulation; Productivity; Price-cap.

1. Introduction

In this article, we examine the concept and measurement of the productivity of highway concessionaires. The topic has become of fundamental relevance considering the major privatizations of concessionaries which have occurred in some European countries (Autostrade in Italy, ASF, SANEF, and SAPRR in France).

There are several reasons why the question of highway operators' efficiency becomes more relevant in a private-oriented competitive framework. A first reason is yardstick competition. If the regulator wants to use incentives to improve the efficiency of

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operators, he needs indicators to compare actual with optimal cost levels for each operator. A second reason regards the relative merits of private vis-à-vis public ownership. Indeed, one of the reasons for advocating privatizations is the supposed greater efficiency of the private sector, although empirical evidence on this point still needs to be consolidated. Comparing efficiency of private versus public operators is a key element for the determination of highway policy. In a recent contribution, Benfratello et alii (2005), using a panel data approach, shed some light on the cost structure of the highway sector in Italy. They estimate a cost function for 20 Italian concessionaires for the period 1992-2003. Their results indicate that private ownership has a positive impact on productivity while regulatory regime (Price cap versus Rate of Return) has no effect on productivity.

Another reason to investigate highway operator efficiency is to determine the scope for scale economies and, thus, the most cost efficient market structure. Last but not least, the measurement of productivity changes is prerequisite for the implementation of price cap regulation. In Italy, for instance, tariff increases are determined as the sum of the change in the retail price index, minus the anticipated changes in productivity (usually referred to as the X factor), plus a quality premium based on accidents and road surface conditions (see Greco and Ragazzi, 2005, Benfratello and alii, 2006). Thus, in order to implement correctly the price cap regulation, regulatory authorities must have a clear understanding of the evolution of productivity both at the sector level and for each single operator.

In order to shed light on the issue of highway operator efficiency several methods can be used. Highway efficiency can be analysed through comparisons among various operators within a single country or across countries. Cross-country comparisons may provide useful information on how different ownership structures or regulatory systems may affect cost efficiency. One may also analyse how the costs of single operators change over time, and how such changes relate to changes in the operating framework of the industry (mainly changes in the market structure and in technology). Other methods rely on the analysis of simple indicators (typically operating cost/vehicle.km). A more comprehensive method relies on the estimation of cost functions. Eventually, elaborating on costs functions, Stochastic Frontier Analysis models can be used in order to estimate the degree of (in)efficiency of various operators.

In the present article, we make use of these various approaches in order to investigate highway operator efficiency. Section 1 is dedicated to the discussion of possible definitions of highway licensees' output, showing the implications of each definition. In Section 2, we estimate a cost function for Italian concessionaires based on a cross section of 18 highway operators for year 2006 and provide estimates of marginal costs for traffic and network as well as a measurement of efficiency of each concessionaire. We estimate also a stochastic cost frontier where an additional single sided disturbance, representing inefficiency, is added to the traditional stochastic disturbance present in the cost function estimate. Such method allows the computation of inefficiency for each single operator, that can be used for yardstick competition. Section 3 analyses the evolution of costs and revenues of Italy's major licensee over two decades. In Section 4, we compare Autostrade with three other main operators and we compare costs and revenues of Italian and French highway concessionaires.

2. How to define and measure productivity?

Productivity is the ratio between output and inputs. In the case of networks, how one should define output is far from clear or generally accepted. There are basically two different approaches: the first refers to traffic (appropriately taking into consideration its composition), the second to the capacity that is offered by the infrastructure.

If one considers output from the point of view of the (total) benefit obtained by the users, traffic would appear the best measure for output, although the quality of service should also be considered (safety, congestion, average speed etc.). If one considers instead the service provided by the operator, its output consists mainly in the provision of a certain capacity, which has a value (and costs) irrespective of the volume of traffic that goes through the infrastructure.

Traffic depends upon the original design of the network and the subsequent evolution of demand; the company managing the network cannot significantly impact the volume of traffic. However, certain costs increase with traffic, depending upon the network. Unlike other network industries (the cost of maintaining an electric grid may be independent from the watt-hours that go through it), in the case of highways, incremental traffic may require additional services (and additional costs) both for toll collection[1] and pavement repair. Traffic (especially HGVs) damages the pavement and thus causes additional costs. Damages may also derive from several other causes such as, for instance, climate (for a survey, see Bruzelius, 2004). It is therefore very difficult to measure the marginal cost of traffic regarding maintenance. Other costs, in particular collection, clearly vary in function of the traffic volume. However, traffic may not suffice to explain correctly operating costs. For instance, Link (2003), who considered operating costs (defined as "*maintenance, operation and renewals*") to be a function of traffic only, obtained models with relatively poor fitting[2].

Levinson and Gillen (1998) consider two components of highway production: "*in general, highway segments produce two outputs: traffic flow which require capacity in terms of the number of lanes, and standard axle loadings which require durability in terms of thickness of the pavement" (Levinson and Gillen, 1998, p. 207).* Further on in their article, Levinson and Gillen use a definition of highway production as the traffic of various vehicle categories. Benfratello and alii (2005) consider that the output is traffic, but the costs also depend on network length. Others, for instance the Italian NARS[3], stress that measures of highway production expressed in terms solely of traffic provide misguiding evidence; according to them the indicators should refer to the costs of the network provided to road users, aside from the actual use that these users may decide to make.

[1] Collection is a service provided by the licensee, but does not add to the utility of users, being a deadweight cost for society.

[2] For a series of models estimated on data from Switzerland, Germany, and Sweden, the models' R^2 were ranging from 0,25 to 0,65.

[3] The NARS (*Nucleo consulenza Attuazione linee guida Regolazione Servizi di pubblica utilità*) is a committee of experts in charge of advising the Ministry of Economics and Finance regarding the regulation of public services.

In conclusion, output may be defined as made up of three components:
- provision of a given capacity,
- throughput of the traffic,
- quality of the service[4] (pavement, safety, collection systems, congestion etc.)

If data about the breakdown of operating costs for each of the three outputs were obtainable we could consider productivity separately for each of the three output components. Productivity in the provision of capacity could be estimated by comparing the network length with the operating costs dedicated to such purpose, and productivity in traffic handling could be estimated by comparing traffic volumes with costs related to toll collection and repairing pavement damage caused by traffic. It would be much more difficult to define a single index for quality. However, since a breakdown of operating costs is generally not available, in the following section we compare total operating costs to traffic and network size.

3. Cost function estimate and measure of efficiency of Italian concessionaires

In this section, we intend to measure the cost efficiency of Italian concessionaires. We first provide the results of a cost function estimation. We subsequently analyse how these results should be interpreted in terms of marginal costs. Eventually, we investigate the measure of inefficiency for the different operators.

3.1 Cost function estimation

We consider the concessionaires' production in terms of traffic and of road capacity. We do not consider the quality of service due to the limitations of the available quality index. Two types of models are used. The first estimates an average cost function and is based on the usual regression techniques. The second estimates a stochastic cost frontier where inefficiency is measured as (positive) deviation from this frontier. With regard to the measurement of inefficiency, we prefer to use the Stochastic Frontier Analysis rather than the class of methods based on Data Envelopment Analysis due to the deterministic nature of this last methodology.

A common simplification, made for the assessment of infrastructure maintenance costs, is the hypothesis of constant marginal costs, even if the evidence is not clear-cut. One of the most frequently advocated advantage is the possibility to use non linear cost functions incorporating variable marginal costs. Although attractive, the intuition of variable marginal costs finds only limited support in the literature: as observed by Link

[4] In the regulatory framework in use in Italy, quality improvements are measured (and corresponding increases in tariffs are granted) on the basis of two indicators: accidents and quality of pavement. This method appears unsatisfactory. Accidents depend primarily on traffic regulations and are to a large extent outside the control of the licensee company. In recent years, accidents have diminished because of the stricter enforcement of speed controls and other similar measures taken at national level, and the decline in accidents has been similar on state roads as on highways. Operating costs for safety improvements are mostly those for road panels, presumably small enough to be disregarded without appreciable effects on the measures of productivity.

(2003), *"in many cases the detected non-linearities were rather weak in the relevant range of traffic variables"* (see also Ozbay et al., 2001, Deller and Nelson, 1991). Consistent with such findings, the simplification of relying on constant marginal costs has been accepted in current highway investment assessment practice as, for instance, in the Federal Highway Administration guidelines (FHWA, 1982) that considers *"cost estimates of pavement wear as a fixed $/Equivalent Single Axle Load Mile"*.

In our models, we consider a cost function where operating costs depend on two variables: capacity and traffic. The most visible challenge is to disentangle the intrinsic correlation among these two variables and isolate the effect of each variable. The dependent variable, operating cost, is defined as the sum of the following costs: 1) raw materials, and intermediate goods; 2) services; 3) rental and leasing; 4) personnel. Data are taken from the annual reports of the concessionaire companies. Amortization and financial costs are not considered as they mostly depend upon the historical costs of the infrastructure and the length of the concession.

The independent variables are defined as follows: Capacity is expressed in weighted kilometres of highway (one kilometre of 3 lanes highway is supposed to be equivalent to 1.5 km of 2 lanes highway) and Traffic is expressed in terms of veh.km. This unit is preferred to other possible units: number of users, pcu.km (personal car units), t.km, ESAL.km (Equivalent Single Axle Load) or GVM.km (Gross Vehicle Mass.km) as it better fits with the purpose of our study. The number of transits would be useful to take into account the costs associated with toll collection but they would prove deceiving for other costs such as road maintenance. Pcu.km would rather be useful to understand traffic flow, ESAL.km or GVM.km would be apt for the estimating costs for pavement renewal but is not relevant for other expenses. Thus, considering that these various measurement units do not have advantages, we will stick to the measurement of traffic in terms of veh.km. We consider only the total flow of vehicles. We decided not to weight car traffic and HGV differently due to the relatively stable share of HGVs in total traffic among the different licensees. Note, as well, that due to the cross section nature of our data, the introduction of input prices in the cost function, that would be consistent with the micro foundation of the efficiency measures, would prove useless for our data: as input prices are invariant across our population the effect of these prices cannot be disentangled from the model's constant. We consider data for year 2006. We concentrate on one single year rather than using panel data. Panel data has already been implemented in previous works on highway concessionaires in Italy (Benfratello and alii (2005)) while we are not aware of any Stochastic Frontier Analysis based on cross section data.

Table 1 provides the data as well as some relevant ratios (cost/km and cost/veh.km) for the investigated concessionaires. A well known feature of Italian highway sector is the strong dichotomy among highway operators: Autostrade per l'Italia (ASPI), without considering its subsidiaries, operates a network of 2,855 km and 48.2 billion veh.km, which is more than half of the total highway traffic; the other concessionaires are notably smaller (Autostrada del Brennero, the second largest operator, accounts for 12 % of total highway traffic). Divergence from the mean is larger for concessionaires with a small network, see for instance RAV for cost/veh.km (11.8 eurocent per veh.km against an average of 3.6 eurocent) or Tangenziale di Napoli as well as Padova-Mestre for cost/km (1,845 and 771 thousand euro per km against an average of 504 thousand euro). This suggests the existence of non linearities together with possible heteroschedasticity that should be taken into account in the model estimation.

Table 1: Italian concessionaires, some descriptive data (2006)

Operator	*Network*	*Capacity*	*Operating costs*	*Traffic*	*Op. costs per km*	*Op. costs per veh.km*
	km	Weighted km (2004)	10^6 €	10^6 veh.km	10^3 €/km	€ cents/ veh.km
Autostrade per l'Italia (ex Autostrade)	2,855	3,324	923	48,214	323	1.9
Autovie Venete	189	182	64.7	2,629	342	2.5
MilanoMare	184	235	89	3,091	484	2.9
Padova - Mestre	41	54	31.6	1,148	771	2.8
SAM. Autostrade Meridionali	52	55	36.9	1,562	710	2.4
Torino - Savona	131	130	33.2	949	253	3.5
Brescia - Padova	182	256	132	5,175	725	2.6
Autostrada del Brennero	314	314	157.6	4,643	502	3.4
Torino- Milano	130	189	61.9	2,150	476	2.9
Torino- Piacenza	168	169	52.9	2,191	315	2.4
ATIVA (Torino- Val d'Aosta)	156	150	54.5	2,190	349	2.5
RAV (Raccordo Aut. Val d'Aosta).	27	27	10.4	88	385	11.8
Centropadane	89	97	26.4	1,007	272	2.6
SAV (Autostrade Valdostane)	68	60	21.6	405	318	5.3
Autostrada dei Fiori	113	115	59.8	1,333	529	4.5
SALT (Soc. Aut. Ligure Toscane)	155	154	61	2,070	394	2.9
SAT (Soc. Autostrada Tirrenica)	37	36	10.1	248	273	4.1
Autocamionale CISA	101	120	32.8	862	325	3.8
Consorzio per le Autostrade Siciliane	268	217	n.a.	1,753	n.a.	n.a.
Strada dei parchi	281	285	57.9	2,296	206	2.5
Tangenziale di Napoli	20	30	36.9	1,053	1,845	3.5
Mean (unweighted)	*265*	*295*	*101.5*	*4,050*	*504*	*3.6*

Based on these data, we estimate a set of costs function. We first estimate a linear model (a). Then we introduce a translog specification (model b), where all coefficients but $\log^2(K)$ are present in the equation and have a significant coefficient. A simplified translog specification is also provided as model (c) on the grounds that it is more parsimonious than the previous model and is nearly as satisfactory considering the usual fitting criteria. Eventually, model (d) is the estimation of a stochastic cost frontier based on model (c). Model (d) includes two error terms: one is the traditional normally distributed disturbance, the other one is a single sided disturbance that represents the inefficiency of each operator compared with the stochastic cost frontier. A similar approach has also been tested for model (a) and (b). However, due to non convergence of the algorithms used for estimation (a situation that is not infrequent in the field of efficiency estimation), such models could not be calibrated.

The models are:

$$co = \beta_0 + \beta_K.K + \beta_T.T + \varepsilon \quad \text{(a)}$$

$$Log(co) = \beta_0 + \beta_T.Log(T) + \beta_{T2}.Log^2(T) + \beta_K.Log(K) + \beta_{TK}.Log(T).Log(K) + \varepsilon \quad \text{(b)}$$

$$Log(co) = \beta_0 + \beta_K.Log(K) + \beta_{TK}.Log(T).Log(K) + \varepsilon \quad \text{(c)}$$

$$Log(co) = \beta_0 + \beta_K.Log(K) + \beta_{TK}.Log(T).Log(K) + \varepsilon + u \quad \text{(d)}$$

where co are operating costs (millions of euro), T is traffic (millions of veh.km), K is capacity (weighted kilometres) and ε is independently (but not necessarily identically) normally distributed disturbance and u follows a non-negative distribution.

The estimates have been made after exclusion of the concessionaire ASPI, considering that this concessionaire is lying far outside the scatter of observations and would have a strong leverage effect on the estimated coefficients. The "Autostrada dei Parchi" has also been excluded because, for historic reasons, it has anomalous, very low, costs per kilometre. "Consorzio Autostrade Siciliane" is not included for lack of data. Consequently, the model is estimated based on 18 concessionaires. The estimations have been made using Limdep package, and they are presented in Table 2. This table features, for each model, an indicator of the quality of fitting (whether adjusted R^2, or Log likelihood, whenever relevant), together with the Root Mean Square Error (RMSE) of the estimated operating costs (which eases the comparison among models when the dependent variable is transformed[5]), the number of observations, as well as the estimated coefficients together with the critical probability associated with their t statistics. Note that the frontier model is estimated with the maximum likelihood method.

[5] RMSE is not included for model (d), because it would not make sense to compare the forecast capability of a frontier model with other model.

Table 2: Estimate of costs function of highway concessionaires (2006 data)

	Model (a) Linear		Model (b) Translog 1		Model (c) Translog 2		Model (d) Frontier (half normal)	
Dependent variable	Costs		Log (Costs)		Log (Costs)		Log (Costs)	
Fitting	adjR²	0.9305	adjR²	0.9458	adjR²	0.9367	LL	6.48
Number of obs		18		18		18		18
RMSE costs		9.39		7.15		8.53		
	Coeff.	P. value	Coeff.	P. value	Coeff.	P. value	Coeff.	P. value
Constant	1.169	0.80	2.849	0.00	3.036	0.00	2.883	0.00
Capacity (K)	0.112	0.14						
Traffic (T)	0.021	0.00						
Log(K)			0.504	0.01	-0.901	0.00	-0.904	0.00
Log(T)			-0.605	0.05				
Log²(T)			0.271	0.01				
Log(K)*Log(T)			-0.593	0.02	0.145	0.00	0.146	0.00

Model (b) and (c) have been estimated using the White heteroschedasticity robust covariance method that corrects for heteroschedasticity of the error term.

Model (a) estimates a constant marginal cost of traffic while capacity has limited explanatory value as its coefficient is not significant at the 10% probability level[6]. Results with translog specification are more satisfactory considering the significance of the coefficients as well as the fitting criteria RMSE. Model (b) provides the best fitting based on the RMSE criteria. Model (c), although slightly inferior to model (b) considering the fitting criteria of RMSE is presented for two reasons. First, it is more parsimonious. Second, model (c) can be used as a base for the estimation of frontier models, whilst estimation of the frontier does not converge when the specification of model (b) is used. This last observation is not univocally interpretable as it may be due both to the intrinsic limitations of the estimation tools and processes or to the inadequacy of the functional form. The choice between specification (c) and specification (b) is however not anecdotal as it provides different indications on the scale economies. As will be illustrated further, while marginal costs of the traffic is increasing in model (b), while it is decreasing in model (c).

Model (d) estimates the stochastic frontier of the operators. The term representing inefficiency is distributed based on an half normal distribution distribution. Exponential and truncated normal have also been tested, but they were found to perform less well than the half normal distribution.

[6] The critical probability associated with the constant is high. However we keep this constant in the model considering the undesirable properties of models without a constant. Note as well that similar estimates based on 2004 data also resulted in a non significant constant, although the critical probability was lower in magnitude (see Massiani and Ragazzi, 2006, for more details).

3.2 Marginal costs

The understanding of marginal costs is not straightforward for models (b) and (c) as they produce a marginal cost that is function of traffic and/or capacity. To illustrate the economic meaning of equations (b) and (c), it is however possible to consider the marginal cost of traffic and capacity of given concessionaires. Table 3 indicates these marginal costs for three concessionaires that correspond to the quartiles of the concessionaires' population (based on increasing operating costs). For comparison purpose, the constant marginal costs of the linear model (model a) is also indicated in the right column.

Table 3: marginal costs of traffic and capacity for three different concessionaires (2006 data)

		Variable Marginal Cost				*ConstantMarginal Cost*	
Quartile (increasing operating costs)	Concessionnaire	Model (b)		Model (c)		Model (a)	
		Traffic	Capacity	Traffic	Capacity	Traffic	Capacity
		€ cent/ veh.km	10^3 €/km	€ cent/ veh.km	10^3 €/km	€ cent/ veh.km	10^3 €/km
Q1	Autocam. CISA	0.9	231	2.4	20		
Q2	Torino Piacenza	1.5	222	2.1	79	2.1	112
Q3	Autovie Venete	1.6	225	2.1	96		

The emerging pattern of the table is that, when using translog specifications, the estimates of the marginal costs are very sensitive to the specification of the model: while model (b) indicates sharply increasing marginal costs of the traffic and quite constant marginal costs of the capacity, model (c) indicates decreasing marginal costs of the traffic and sharply increasing marginal costs of the capacity. The marginal costs of the linear model, that are fixed by nature, have values that are within the minimum and maximum of the marginal costs of the translog models.

Our findings suggest that, while attractive due to its high level of flexibility the translog specification exhibit a high sensitivity of the results to the functional specification. This may be in favour of a more modest, linear model whose limitation of providing constant marginal costs may be acceptable considering the limited range of variability in the dimension of the concessionaires under scrutiny.

3.3 Inefficiency measures

Based on model (d), we estimate for each concessionaire the inefficiency, that is E($u \mid u+\varepsilon$). The estimation is based on the method presented in Jondrow et al. (1982). The results are presented in Table 4. Two considerations should be made. First, the estimation of inefficiencies is contingent upon the choice of the distribution for the term u, but the relative inefficiencies are usually found to be highly correlated between different distribution assumptions. This is confirmed in our case, where the correlation between single inefficiencies estimated using the half normal distribution and the ones using exponential distribution is 0.98. This suggests that, while an absolute interpretation of inefficiencies is not robust, the relative magnitude of inefficiencies is informative about the efficiency of each concessionaire. Second, the measure of inefficiency is contingent upon the specification of the cost function. This implies that a measure based on model (b) would provide different results. There is however considerable evidence that the impact of the specification of the cost function on the individual estimates is limited (cf. for instance the evidence collected, in other fields of applied economics, by Rosko and Mutter, 2007, p. 143).

Table 4 indicates the inefficiency of each concessionaire. Based on these data, one could conclude that operators like Tangenziale di Napoli, Autostrada dei Fiori, as well as SAV, RAV and Autostrada del Brennero exhibit a higher level of inefficiency, while Torino-Piacenza, SAT and Centropadane, are among the most efficient.

Table 4: Inefficiency measure for each concessionaire (model d) [7]

Autostrade Venete	1.08	ATIVA	1.09
Milano Mare	1.12	RAV	1.19
Venezia Padova	1.10	Centropadane	1.06
SAM	1.09	SAV	1.20
Torino - Savona	1.12	A. dei Fiori	1.34
Brescia - Padova	1.10	SALT	1.13
A. del Brennero	1.19	SAT	1.05
Torino Milano	1.11	A. della Cisa	1.15
Torino - Piacenza	1.07	Tangenziale di Napoli	1.22

Our analysis suggests, however, that more effort should be dedicated to the analysis of the efficiency of highway operators to implement “yardstick competition”.

3.4 Toll collection costs

Eventually, one may want to consider how much these compared efficiencies may be affected by one single identifiable cost, that is the cost of toll collection. A rough estimate of the efficiency in toll collection may be obtained by comparing the personnel employed in collection with traffic volumes.

[7] The inefficiency measure is given as $\exp(E(u \mid u+\varepsilon))$. Thus a figure of 1.20 indicates an inefficiency equal to 20% of the minimum operating costs.

Table 5: Toll collection costs of concessionaires (2004)

	Toll collection staff	*Toll collection staff/ km*	*Toll collection staff/ 10^9 veh.km*
Autostrade per l'Italia	2,760	0.97	59
Autovie Venete	267	1.48	118
Milano Mare	454	2.48	153
Autostrade del Brennero	398	1.27	88
RAV (Raccordo Autostradale Val d'Aosta).	8	0.30	99
Centropadane	72	0.81	80
SALT (Società Autostrade Ligure Toscane)	194	1.26	97
Autocamionale CISA	61	0.51	74
Strada dei parchi S.p.A	293	1.04	133
Tangenziale di Napoli	288	14.24	278

Remark: only concessionaires whose information about employees categories was sufficiently detailed could be included in this table.

As illustrated in Table 5, differences are very marked: Autostrade per l'Italia (ASPI), the major licensee, employed 59 collectors per billion vehicle.km, compared to 153 by "Milano-Mare" and 278 by "Tangenziale di Napoli". However, such differences can not be simply attributed to different degrees of efficiency since they also depend on factors such as the length of the network, the number of gates and the average travelling distance of vehicles on each concessionaire's network.

4. ASPI: a twenty years case study

In this section, we investigate the historic evolution of the productivity of "Autostrade" which in 2003 changed its name to "Autostrade per l'Italia" (ASPI), excluding the subsidiaries that manage other highway sections as well as other subsidiaries which deal with activities that are not strictly related to highway operation[8]. Indeed, the group went through major organisational changes in 2003, while the activity of the company operating the highway has remained stable over time.

We consider the years 1985 to 2005. Table 6 provides the following information: 1) Output is expressed in terms of network length (km of network) and in terms of traffic (millions of veh.km). The composition of traffic is not considered because it shows a stable pattern during the whole period[9]; 2) Revenues[10]; 3) Workforce (at year end) as

[8] For instance, from 1996 on, the consolidated accounts also include Pavimental, a company operating in road works that accounted for 7 % of the group turnover in 1997. Less important , but even more remote from highway operation, is the activity of Autostrade Telecomunicazioni created in 1996.

[9] The maximum share of personal cars is 78 % in 1987, the minimum is 75,8 % in 2004.

[10] For years 1985-1995, data are from R&S annual yearbooks (Mediobanca) and revenues are defined as total sales ("*fatturato lordo*"). For years 1996-2005 data are from the company's financial reports and revenues are defined as the value of production ("*valore della produzione*"), i.e. Sales ("*fatturato*") plus change in work in progress ("*variazione dei lavori in corso*").

well as toll employees (collectors); 4) Operating costs[11], indicating separately "personnel costs" and "goods and services" (total operating costs include also the value of stock variation which is not detailed in the table). Subsequently table 7 concentrates on the most relevant ratios (revenues per km and veh.km, costs per km and veh.km as well as personnel costs/employee).

All euro data are homogenised at 2004 prices. The deflator is the production price index of industrial goods as provided in the National Institute of Statistics (ISTAT) yearbooks. To ensure homogeneity of data, the same deflator is also applied to deflate personnel costs. Revenues and operating costs at current prices are reported in the appendix (table 12).

Table 6: descriptive data of Autostrade, 1985-2005

Year	Network	Traffic	Employees			Revenues	Operating costs		
			Toll employees	Others	Total		Goods and services	Personnel costs	Total
	km	10^6 veh.km				(10^6 € 2004)			
1985	2,632	22,049	3,979	2,891	6,870	1,071	257	224	480
1986	2,674	23,696	4,194	3,051	7,245	1,251	304	249	552
1987	2,774	25,804	4,351	3,269	7,620	1,405	390	280	669
1988	2,791	27,841	4,581	3,524	8,105	1,396	440	311	746
1989	2,796	29,963	4,692	3,680	8,372	1,419	420	339	743
1990	2,796	31,190	4,771	3,757	8,528	1,460	334	358	678
1991	2,796	31,759	4,761	3,690	8,451	1,605	411	389	783
1992	2,799	33,027	4,735	3,698	8,433	1,699	472	407	824
1993	2,799	33,238	4,644	3,679	8,323	1,627	382	404	773
1994	2,816	34,176	4,419	3,568	7,987	1,707	317	439	747
1995	2,854	35,383	4,266	3,631	7,897	1,704	330	434	757
1996	2,854	36,035	4,169	3,568	7,737	1,753	346	401	740
1997	2,854	37,554	3,995	3,437	7,432	1,800	393	403	786
1998	2,854	39,260	3,832	3,428	7,260	1,920	426	385	805
1999	2,854	40,359	3,568	3,518	7,086	2,070	513	392	929
2000	2,854	41,810	3,366	3,527	6,893	1,953	458	361	818
2001	2,854	43,315	3,180	3,510	6,690	2,148	469	347	820
2002	2,854	44,603	3,098	3,478	6,576	2,273	443	360	801
2003	2,854	45,858	2,930	3,452	6,382	2,382	483	350	833
2004	2,855	46,703	2,760	3,602	6,362	2,516	500	343	848
2005	2,855	46,769	2,633	3,308	5,941	2,535	523	331	862

[11] Operating costs are the sum of personnel costs (*"costi per il personale")* plus purchases of goods and services (*"acquisti e prestazioni di terzi, costi diversi di esercizio")* minus the increase of work in progress (*"variazione lavori in corso")*. For the years 1985-1995, data are from R&S annual yearbook (Mediobanca). For the years 1996-2005 data are from the company's financial reports.

The length of the network increased very little up to 1995, and not at all thereafter[12], while traffic more than doubled. Revenues (at constant 2004 prices) increased more than traffic as real tariffs (revenues per veh.km at constant prices) increased from 4.86 eurocents per veh.km in 1985 to 5.42 eurocents in 2005. Real revenues per km increased from 407,000 euro in 1985 to 597,000 in 1995 and to 888,000 in 2005 (2004 prices).

Operating costs per km (table 7), although somewhat variable from year to year, after an initial increase to 267,000 euro (2004 prices) in 1988, remained relatively stable around this level for the following decade. After the privatization (with a peak in costs in 1999) operating costs per km increased from 287,000 euro in 2000 to 302,000 euro in 2005 (2004 prices). We do not know if and to what extent the increase of costs for the purchase of goods and services after privatization was due to higher spending for road resurfacing.

Operating costs per veh.km declined from 2.7 eurocents in 1988 to 2.0 eurocents in 1996 and diminished only slightly thereafter (but for an exceptional peak in 1999). The decline of operating costs per km, in spite of the sharp increase in traffic, is essentially due to the increase of efficiency in collection. The introduction of automated collection systems, which started in the early '90s, made it possible to reduce the number of collectors (personnel employed in toll collection) from a peak of 4,735 in 1992 to just 2,663 in 2005. This decline had already occurred, to a large extent, before privatization. Other employees declined somewhat from the early'90s to around 3,400 before privatisation and remained stable thereafter. Total personnel costs declined in real terms, in spite of the substantial increase of real average wages (see table 7).

[12] This holds even when one considers the number of lanes offered by the highway. Actually, if we take into consideration this element, the increase in capacity is only 10 % between 1987 and 2004.

Table 7: unit costs and revenues of ASPI (1985-2005)

Year	Revenues/km	Revenues/veh.km	Cost/km	Cost/veh.km	Personnel costs/ employee
	10^3 € 2004/km	€ cent/veh.km	10^3 € 2004/km	€ 2004/veh.km	10^3 € 2004
1985	406.9	4.9	182.4	2.18	32.6
1986	467.7	5.3	206.6	2.33	34.4
1987	506.5	5.4	241.3	2.59	36.7
1988	500.0	5.0	267.4	2.68	38.4
1989	507.4	4.7	265.6	2.48	40.5
1990	522.3	4.7	242.3	2.17	42.0
1991	574.0	5.1	280.1	2.47	46.0
1992	607.1	5.1	294.2	2.49	48.2
1993	581.1	4.9	276.0	2.32	48.6
1994	606.0	5.0	265.3	2.19	55.0
1995	597.0	4.8	265.1	2.14	54.9
1996	614.4	4.9	259.2	2.05	51.9
1997	630.5	4.8	275.2	2.09	54.3
1998	672.7	4.9	282.1	2.05	53.0
1999	725.4	5.1	325.5	2.30	55.3
2000	684.2	4.7	286.7	1.96	52.4
2001	752.5	5.0	287.2	1.89	51.9
2002	796.4	5.1	280.8	1.80	54.7
2003	834.6	5.2	291.9	1.82	54.8
2004	881.4	5.4	297.0	1.82	53.9
2005	888.0	5.4	301.8	1.84	55.8

Figure 1 provides a graphical representation of the main indicators[13]. We may summarize the main findings as follows: 1) there is no evidence of any gain in efficiency following privatization; 2) revenues per veh.km. increased by more than the price index (production prices of industrial goods), i.e. tariffs increased in real terms, from 1995 on; 3) this, and the sharp increase in traffic, caused an even larger increase of revenues while operating costs remained substantially stable; 4) there is no evidence that the increase of traffic appreciably increased operating costs; actually, the automation of collections allowed the company to sharply reduce the number of collectors.

[13] In the year 1999, when the company was privatized, there was an exceptionally high increase of both revenues and costs. The decrease from 1999 to 2000 is due to the fact that the production prices index increased by more than nominal revenues.

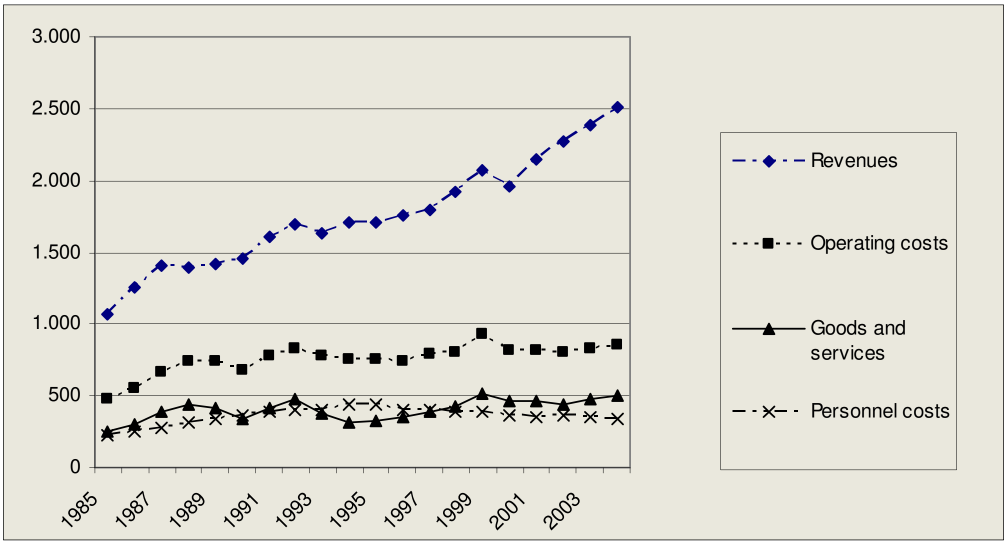

Figure 1 - costs and revenues of ASPI (1985-2004, million euro, 2004 prices)

Amortization and provisions are another major component of total costs, in addition to operating costs and financial charges. Since the company invested very little from the early '90s on, over this period amortization and provisions remained substantially constant in monetary terms (see table 13 in the appendix) and declined in real terms, from over 60% of operating costs in the mid '90s to 40 % in 2004 (excluding goodwill amortization[14]). From 1995 to 2004, amortization plus operating costs declined by 4% to 1.18 billion euros (at 2004 prices) while revenues increased by 48% to 2.51 billion euros.

5. Comparison among operators

5.1 Comparing Autostrade with three other highway operators in Italy

In this section, we compare ASPI with three other major concessionaires: Brescia-Padova (BSPD), Autostrada del Brennero (BREN), Autostrada Torino-Milano (TOMI) excluding their subsidiaries.

The data considered (table 8) are: network length (kilometres), traffic (light vehicles + heavy vehicles) expressed in millions of veh.km, operating costs (purchase of goods and services + personnel costs), total number of employees (and the number of toll collectors when available), revenues[15]. Operating costs and revenues are expressed in 2004 euro using the production price index. Revenues include, in addition to highway tolls, other incomes, mainly sub-concession fees paid by restaurants and petrol stations.

The network length of all four licensees remained unchanged; traffic increased by 30-35%, with the exception of TOMI where traffic increased by only 17% perhaps due to

[14] From 2003 on, amortization more than doubled, but this was entirely due to the amortization of the "book" capital gain ("avviamento") following the group reorganization.

[15] Revenues are defined as "*valore della produzione*", ie. Sales ("*fatturato*") plus change in work in progress ("*variazione dei lavori in corso*").

works which reduced substantially the potential traffic flow. Comparing revenues to traffic we observe that the average toll (at constant prices) declined for BSPD, remained about unchanged for BREN and increased instead sharply for TOMI, whose revenues increased by twice as much as traffic. Also revenues of ASPI increased by much more than traffic, but this was due mostly to higher income from royalties and sub-concessions while real tolls did not increase much.

Operating costs per veh.km declined by 14-17%, except for TOMI (table 9). This was due mostly to the increasing use of automated collection systems which allowed a sharp cut in personnel employed in collection, particularly relevant in the case of ASPI. ASPI has the lowest operating costs per veh.km, almost half those of BREN.

The very steep increase of real profits in this period is the consequence of revenues increasing by much more than operating costs, while capital costs (depreciation and financial costs) declined in real terms.

Table 8: Comparison of Autostrade with three other concessionaires (1997-2006)[16]

a - Network, costs and revenues

	Network			*Traffic*			*Operating costs*			*Revenues*		
	kilometres			(10^6 veh.km)			(10^6 € 2004)			(10^6 € 2004)		
	1997	2006	Δ	1997	2006	Δ	1997	2006	Δ	1997	2006	Δ
ASPI	2,854	2,855	0%	37,554	48,214	28%	786	840	7%	1,800	2475	38%
BSPD	183	183	0%	3,864	5,175	34%	106	120	13%	178	211	19%
BREN	314	314	0%	3,437	4,643	35%	129	144	12%	191	249	30%
TOMI	127	127	0%	1,838	2,150	17%	46	56	22%	88	120	36%

b - Employees

	Employees								
	Total			Toll employees			Other employees		
	1997	2006	Δ	1997	2006	Δ	1997	2006	Δ
ASPI	7,432	5,695	-23%	3,995	2,522	-37%	3,437	3,173	-8%
BSPD	835	708	-15%						
BREN	864	946	9%	407	388	-5%	457	558	22%
TOMI	457	459	0%	215			242		

[16] Brennero Highway costs include the use of “renewal fund” (“fondo di rinnovo”). Operating costs of the Highway Brescia-Padova show large fluctuations over the years - around 100 millions euro from 1997 to 2000, around 80 million euros from 2001 to 2003 and around 120 thereafter. This is due essentially to variations in the cost of external services (“costo per i servizi”). Data for the highway Torino-Milano are difficult to estimate, because the company was merged into SATAP (a company that operates the highway between Torino and Piacenza) in 2003. Moreover, revenues and operating costs are affected by the construction of a high speed rail track along the highway. Part of the construction operations have been undertaken by the highway operating company and reimbursed by the rail company. Costs and revenues of such activities have been estimated and excluded from the figures shown in the table, which thus refer only to activities pertaining to the highway

Table 9: Comparison of Autostrade with three other concessionaires, unit costs (1997-2006)

	Cost/network km (10^6 € 2006)			Cost/10^6 veh.km (€ cent 2006)			Revenues/veh.km (€ cent 2006)		
	1997	2004	Δ	1997	2004	Δ	1997	2004	Δ
ASPI	0.28	0.29	7%	2.09	1.74	-17%	4.79	5.13	7%
BSPD	0.58	0.66	13%	2.74	2.32	-15%	4.61	4.08	-11%
BREN	0.41	0.46	12%	3.75	3.10	-17%	5.56	5.36	-3%
TOMI	0.36	0.44	22%	2.50	2.60	4%	4.79	5.58	17%

Costs per million of veh.km for three operators declined markedly, mainly due to the automation of collection which allowed a sharp reduction in the number of collectors, especially by ASPI. ASPI has the lowest unit operating costs. Regarding cost per kilometre of highway, Brescia - Padova (BSPD) costs are more than double compared with those of ASPI, and they exhibit the sharpest increase over the period. The Brenner highway has the highest costs per veh.km, but it succeeded in reducing costs more than the others[17].

5.2 Comparison between Italian and French highway operators

In this section we compare the operations of highway concessionaires in France with those in Italy. There are eight highway concessionaires in France, six of them are part of three groups, namely: ASF (Autoroutes du Sud de la France together with ESCOTA - autoroutes Esterel Côtes d'azur Alpes), SANEF (Société des Autoroutes du Nord et de l'Est de la France together with SAPN- Société des Autoroutes Paris Normandie) and APRR (Autoroutes Paris Rhin Rhône together with AERA). There is a rough geographical split of the highway network with ASF operating in the southern part of the country, SANEF in the area north and east of Paris and APRR in the Paris-Lyon corridor and in the Alps region. The two other concessionaires are Cofiroute (Paris-Bordeaux Corridor with some extensions in south-west France) and Alis (which started operations in 2005 on a 125 km route in Normandy).

[17] In its bookkeeping, Brennero highway makes use of a special fund called renewal fund. In the computation of costs, we take into account the use of this fund. This however makes the computation of costs subject to more uncertainty as it gives the company some discretionality in the use of the fund.

Table 10: Descriptive data of highway concessionaires in France (2005 data)

Group	*Operator*	*Network size*	*Traffic*	*Staff*	*Revenues*	*Operating costs*		
						Purchase of goods and services	*Personnel costs*	*Total*
		km	veh.km	units	10^6 € (2005)			
SANEF Group		1,742	14,200	N. A.	1,152	108	142	249
incl.	SANEF	1,374	11,048	2,380	N. A.	N. A.	N. A.	N. A.
incl.	SAPN	368	3,198	728	265	39	32	71
ASF Group		3,422	32,603	7,975	2,474	218	336	554
incl.	ASF.	2,963	26,332	5,665	1,958	158	258	416
incl.	ESCOTA	459	6,271	1,828	516	60	78	138
APRR Group		2,205	19,989	4,391	1,571	155	190	345
incl.	APRR	1,810	15,896	3,236	1,210	111	146	257
incl.	AREA *	384	4,047	1,143	361	44	44	88
Cofiroute		928	9,041	1,919	889	91	89	180

Note: AREA data are for year 2003.

Revenues of French operators (Table 10) are almost entirely from tolls, with only a few million coming from sub-concessions, which represent instead a sizeable portion of revenues of Italian operators.

Table 11: Operating ratios of French highway concessionaires and comparison with Italian concessionaires (2005 data, current prices, unless specified)

Group	*Operator*	*Traffic intensity*	*Operating costs/ network km*	*Operating costs/ veh.km*	*Revenues**/ network km*	*Revenues**/ veh.km*
		10^6 veh.km/ km	10^3 €/km	€ cent/ veh.km	10^3 €/km	€ cent/ veh.km
SANEF Group		8.2	143	1.8	661	8.1
incl.	SANEF	8.0	N. A.	N. A.	N. A.	N. A.
incl.	SAPN	8.7	193	2.2	719	8.3
ASF Group		9.5	162	1.7	723	7.6
incl.	ASF.	8.9	140	1.6	661	7.4
incl.	ESCOTA	13.7	301	2.2	1,124	8.2
APRR Group		9.1	156	1.7	712	7.9
incl.	APRR	8.8	142	1.6	669	7.6
incl.	AREA *	10.5	229	2.2	940	8.9
Cofiroute		9.7	194	2.0	958	9.8
Weighted Average France (2005)		9.1	160	1.8	734	8.0
ASPI (2005)		16.4	314	1.9	924	5.6
Weighted Average Italy (without ASPI) (2004)		13.2	379	3.1	710	6.2

* AREA data are for year 2003.
** Revenues are defined as: turnover ("*chiffres d'affaires*") for French concessionaires, net toll revenues ("*ricavi netti da pedaggio*") for Italian concessionaires, except for ASPI where it refers to toll and concession revenues.

Traffic intensity in France is well below that of Italy (Table 11). In spite of this, the operating costs per veh.km of Italian concessionaires are more than 50% higher than those of the French concessionaires, and their operating costs per km are more than double. This difference is partially due to the fact that average personnel costs are 16% higher in Italy (the average annual cost per employee is around 44,000 euro for French concessionaires (2005) and around 51,000 euro in Italy (2004)). Another reason may be the very large difference in the size of the operators in France and in Italy. Although scale economies did not clearly emerge from the analysis of 18 Italian operators, we are unable to exclude the relevance of scale economies for large size differences; this is consistent with the observation that ASPI has much lower operating costs than all the other smaller concessionaires in Italy. Differences in operating costs in the two countries are however strikingly large and this would certainly deserve further investigation.

6. Conclusions

Measuring the productivity of highway concessionaires is very relevant, especially if a price cap regulation is applied. Productivity of highway concessionaires is generally defined as the ratio of traffic to costs. However, the volume of traffic is outside the control of the operating company, depending mostly upon the original design of the infrastructure and the growth of the economy. The output of a company operating an existing infrastructure may best be measured in terms of the provision of a given capacity plus incremental services for traffic, including quality of service. To measure productivity one should consider only operating costs, since amortization and financial costs depend upon historical investment costs and length of the concession.

A cross section analysis of 18 Italian concessionaires shows that:1) operating costs depend on both traffic and capacity (size of the network); 2) economies of scale may be relevant, but they do not emerge clearly on the basis of our estimations. Translog specifications, that would be suitable for the description of scale economies, provide sharply different estimates of scale economies for models with slightly comparable fitting; 3) based on Stochastic Frontier Analysis, we find large differences in cost efficiency among operators, suggesting that there is room for yardstick competition.

Data over two decades for the major Italian concessionaire indicate that: 1) the volume of traffic doubled and tariffs were also increased in real terms, thus revenues per network km (at constant prices) more than doubled, reaching 3 times operating costs; 2) the increase of traffic did not noticeably increase operating costs (at constant prices), as the automation of collections allowed the company to sharply reduce the number of collectors; 3) there is no evidence of significant gains in efficiency following privatization.

The analysis of three other main italian concessionaires, over the period 1997-2004, confirms that the increase in traffic did not result in comparable increases in operating costs, while there are large differences in cost efficiency among operators.

Finally, a comparison between Italian and French concessionaires shows that the latter have much lower operating costs, which cannot be entirely explained by economies of scale or lower personnel costs.

On the whole, the evidence that is collected in this article casts doubt on the validity of the competitive framework prevailing in the highway industry in Italy. There is no evidence that the privatisation of Autostrade improved efficiency, costs in the industry are much higher than in France, revenues have increased more than costs leading to the creation of large rents that regulation should have avoided.

References

Benfratello, L., Iozzi, A. and Valbonesi, P. (2005), “Privatisation, regulation and productivity in the Italian motorway industry”, Marco Fanno Working Paper n 2. Università di Padova.

Benfratello, L., Iozzi, A. and Valbonesi, P. (2006), "Autostrade", *Rivista di Politica Economica*, March-April 2006, pp. 329-364.

Bruzelius, N. (2004), “Measuring the marginal cost of road use. An international survey”, Swedish National Road and Transport Research Institute, VTI medelande 963A, 54 p.

Deller, S.C. and Nelson C.H. (1991) "Measuring the economic efficiency of producing rural road services", *American Journal of Agricultural Economics*, Vol. 73, 1, pp. 194–201.

Federal Highway Administration (FHWA) (1982) "Final report on the federal highway cost allocation study: report of the secretary of transportation to the United States congress", Washington DC.

Greco, A. and Ragazzi, G. (2005) “History and Regulation of Italian Highway Concessionaires”, in Ragazzi, G. and Rothengatter, W. (editors) “*Procurement and Financing of Motorways un Europe”*, Elsevier, Amsterdam, pp. 121-133.

Jondrow, J., Lovell, C. A. K., Materov I. S. and Schmidt P. (1982), "On the estimation of technical inefficiency in the stochastic frontier production function model", *Journal of Econometrics*, Vol. 19, pp. 233-218.

Levinson, D. M. and Gillen D. (1998) "The full cost of intercity highway transportation", *Transportation Research D* , Vol. 3, 4: pp. 207-223.

Link, H. (2003) "Estimates of marginal infrastructure costs for different modes of transport" *43rd Congress of the European Regional Science Association*: 22 p.

Massiani, J., Ragazzi, G. (2006), "Production and productivity of Italian highway concessions” *Scientific meeting of the Società Italiana d'Economia dei Trasporti (Italian society of Transport Economics).* Trieste, June 2006. Published in: I trasporti ed il mercato globale, Edited by Polidori G., Borruso G., Danielis R., Franco Angeli editor, Milano, pp. 277-285.

Mediobanca, Annuario R&S (Ricerche e Studi), yearly edition from 1985 to 2005, Milano.

Ozbay, K., Bartin, B and Berechman J. (2001), "Estimation and evaluation of full marginal costs of highway economics in New Jersey", *Journal of Transportation Statistics*, Vol. 4, 1, pp. 81-103.

Ragazzi, G., (2004), Politiche per la regolamentazione del settore autostradale e il finanziamento delle infrastrutture, *Economia Pubblica*, 34(4), pp. 5-33.

Rosko, M. D., and Mutter, R. L. (2007), Stochastic Frontier Analysis of Hospital Inefficiency: A Review of Empirical Issues and an assessment of robustness, *Medical Care Research and Review*.

Appendix

Table 12: ASPI - Revenues[18] and operating costs at current prices

	Revenues 10^6 € (current prices)	*Total Operating costs* 10^6 € (current prices)	*Income/veh.km* € cent/km (current prices)
1985	639	286	2.9
1986	747	330	3.2
1987	803	412	3.1
1988	889	476	3.2
1989	958	501	3.2
1990	1,026	476	3.3
1991	1,165	569	3.7
1992	1,258	610	3.8
1993	1,248	593	3.8
1994	1,359	595	4.0
1995	1,463	650	4.1
1996	1,535	647	4.3
1997	1,595	696	4.2
1998	1,704	714	4.3
1999	1,833	822	4.5
2000	1,833	768	4.4
2001	2,055	784	4.7
2002	2,179	768	4.9
2003	2,319	811	5.1
2004	2,516	843	5.4
2005	2,637	896	5.6

[18] Revenues refer to gross turnover ("*Fatturato Lordo*") for years 1985-95 and production value (*Valore della produzione*) from 1996 on.

Table 13: ASPI - Allowances for maintenance and amortization funds

Year	*Amortization*					*Provisions for maintenance fund*	*Total (amortization + provisions)*	
	Amortization of goodwill	Deferred charges	Financial	Industrial	Total			
	10^6 € 2004							10^6 € (current prices)
1985		1	150	152	**303**		**303**	181
1986		1	194	187	**382**		**382**	228
1987		3	125	219	**347**		**347**	213
1988		4	155	213	**372**		**372**	237
1989		6	172	205	**383**		**383**	259
1990		7	179	220	**407**		**407**	286
1991		10	197	214	**421**		**421**	305
1992		11	212	214	**436**		**436**	323
1993		10	228	207	**445**		**445**	341
1994		9	248	197	**455**		**455**	362
1995		8	283	182	**474**		**474**	407
1996		7	268	53	**328**	76	**404**	354
1997		7	140	58	**206**	196	**401**	356
1998		7	141	54	**202**	247	**450**	399
1999		8	144	57	**209**	194	**403**	357
2000		10	137	65	**212**	101	**313**	294
2001		11	135	68	**214**	144	**358**	**343**
2002		13	139	76	**227**	124	**352**	**337**
2003	448	28	107	52	**635**	144	**779**	**759**
2004	436	34	108	45	**624**	151	**775**	**775**

Source: R&S yearbook until 2000. Annual Reports from 2001 on.