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PRODUCTIVE EFFICIENCY AND REGULATORY REFORM: THE CASE OF VEHICLE INSPECTION SERVICES

Francesc Trillas*, Daniel Montolio†, Néstor Duch‡

Abstract:

Measuring productive efficiency provides information on the likely effects of regulatory reform. We present a Data Envelopment Analysis (DEA) of a sample of 38 vehicle inspection units under a concession regime, between the years 2000 and 2004. The differences in efficiency scores show the potential technical efficiency benefit of introducing some form of incentive regulation or of progressing towards liberalization. We also compute scale efficiency scores, showing that only units in territories with very low population density operate at a sub-optimal scale. Among those that operate at an optimal scale, there are significant differences in size; the largest ones operate in territories with the highest population density. This suggests that the introduction of new units in the most densely populated territories (a likely effect of some form of liberalization) would not be detrimental in terms of scale efficiency. We also find that inspection units belonging to a large, diversified firm show higher technical efficiency, reflecting economies of scale or scope at the firm level. Finally, we show that between 2002 and 2004, a period of high regulatory uncertainty in the sample's region, technical change was almost zero. Regulatory reform should take due account of scale and diversification effects, while at the same time avoiding regulatory uncertainty.

Keywords: Productive Efficiency, Regulatory Reform, Vehicle Inspections.

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1. Introduction

Though the process of quantifying productive efficiency is relatively easy, drawing lessons from it, and then applying these lessons to the area of regulatory reform, is rather harder. Specialists in productive efficiency measurement are seldom experts on regulatory reform, and vice-versa. In this study, we illustrate how recent developments in the theory of regulation (see Armstrong and Sappington, 2005) can be used to draw lessons from a standard exercise in productive efficiency using a new data set of inputs and outputs in the vehicle inspection sector.

Vehicle inspections are compulsory in many jurisdictions in the interest of environmental protection and safety. The rationale for this public intervention is that, in their absence, the quantity of polluting emissions by vehicles and car accidents would be too high, relative to social surplus maximizing levels. Some articles in the academic literature have used data from the US to dispute this rationale.[1] However certain countries, especially in the developing world (such as Chile and China), have recently introduced or reformed their compulsory vehicle inspection systems and, as yet, there are no reports of countries abolishing the practice.

There are wide international disparities in the economic provisions for vehicle inspection. In some jurisdictions, such as the UK or many US states, many different units are authorized to perform inspections, including repair garages. In others, like Spain or Chile, inspections may only be made at official stations. Even in countries in which repair garages are not authorized, the system of selecting the firms that can perform inspections differs widely, for instance, between jurisdictions that operate stations under state ownership (e.g. Sweden) and others where the government grants concession contracts to private operators (as in many Spanish regions). In the latter cases, the suitability of the concessions scheme has sometimes been questioned. Proposals have been made to liberalize the system and to base it on a framework of administrative authorizations.

Since 1985, vehicle inspections in Spain have been regulated by a system of concession contracts in which tariffs and contractual clauses are set by regional governments and the technical requirements that inspections have to fulfil are determined by the central government. The legislation was strict on the area of incompatibilities, prohibiting firms in the automobile sector from applying for vehicle inspection concessions. This regulatory framework evolved into a system of regulated monopolies in the different regions of Spain. In the years 2000 and

[1] See Hubbard (1997, 1999, 2002), Merrell et al. (1999), Sutter and Poitras (2002) and Poitras and Sutter (2002).

2003 the central legislators introduced a system of authorizations to replace concessions, leaving the implementation of the new plan to the discretion of the regional governments. In general the regional governments have been quite reluctant to liberalize the system. The Catalan regional government, responsible for the inspection units examined in this study, was contemplating a shift from concessions to authorizations towards the end of our sample period, in 2004.

Vehicle inspections are part of a sector in worldwide expansion, as witnessed by the fact that firms involved in vehicle inspections also issue certifications of other kinds, in growing sectors such as environmental or industrial quality. In the case of vehicle inspections, the demand derives from the demand for vehicle use,[2] which is increasing all over the world. The demand also responds to social preferences, as reflected in the rules to protect the environment and to improve safety. Arguably, environmental and safety concerns have also increased worldwide in recent years.

Moreover, as we noted above, the regulation of the vehicle inspection sector is changing. The sector is opening up to private or foreign investment and competition and in most countries regulatory reform is underway. Several multi-national firms (such as TÜV-Rheinland, SGS, DEKRA, ATISAE and Applus) are establishing a foothold in the global market.

In this context of regulatory change in an expanding sector, productive efficiency measurement can help to answer the following questions. What is the minimum efficient scale of production? Is there technical progress? Are there scope or diversification economies? And are managers behaving in a cost minimizing way? This information can guide decisions on introducing competition or bidding for monopoly concessions, or on the need for different forms of incentive regulation, such as price caps or yardstick competition.

Given the very special nature of this industry, it is important to provide independent and objective quantitative assessments of the desirability of regulatory reforms. Consumers (car owners, not the overall population) devote a small proportion of expenditure to vehicle inspections: in our sample units, about 30€ (approximately 38US$ in May 2006) for inspections that take place every one or two years, depending on the age of the vehicle. Therefore, inspection costs for consumers do not trigger the level of public awareness of, say, public utilities rates such as electricity or water. However, given their compulsory nature, vehicle

[2] Legislation in Spain requires that vehicles between 4 and 10 years old must have a technical inspection every two years at an authorized station, and vehicles older than this must have an annual inspection.

inspections are a steady source of cash for operating firms in a sector in which demand is growing. We thus conjecture that firms have a far greater influence in policy design and implementation than do consumers. Therefore, there is high potential for regulatory capture.[3] The complexity of the interaction between firms and policy makers increases with the presence of multi-national operators. How to design national or even (in decentralized countries like Spain) regional regulation to benefit consumers when some of potential firms are powerful multi-nationals is an important question.

In this study, we use the Data Envelopment Analysis (DEA, hereafter) methodology to measure productive efficiency for 38 vehicle inspection concessions for the period 2000-2004 in Catalonia (Spain). With the efficiency scores obtained we also perform a second-stage Tobit analysis of the likely determinants of the efficiency scores observed, and we report and decompose Malmquist indices to quantify the sources of productivity change.

As far as we know, only two other DEA analyses have been applied to vehicle inspections in the economics literature. Both use samples of publicly owned vehicle inspections services. Ylvinger (1998), studying Swedish vehicle inspections, reports an average inefficiency level of 9%. Odeck (2000), on Norwegian inspections, reports an average inefficiency of more than 20%; like us, this author decomposes a Malmquist index of productivity change, finding that variations in productivity are mainly explained by technical change. Unlike our study, however, neither of these articles quantifies scale economies or the determinants of inefficiency. Therefore, our study is, to our knowledge, the first to perform a DEA analysis of privately operated vehicle inspections, to quantify scale economies, and to study the determinants of efficiency differentials in this sector.

We show that in our sample there is potential for an average increase in technical efficiency of 13.1% (14.5% if we take the last year in the sample). We also compute the scale efficiency scores, showing that only vehicle inspection units in territories with very low population densities operate sub-optimally. We demonstrate that the introduction of new units in the most densely populated territories (a likely effect of some form of liberalization) would not be

[3] See Grossman and Helpman (2001). For the years under study, the units in the sample were *de facto* under a regime of rate of return regulation, that is, entry was not allowed and tariffs were set to sustain an "economic and financial balance". There were no clearly established procedures to fix tariffs, which were set at the initiative of the firms; the government could decide whether to completely accept, partially accept, or reject the operators' demands. It is well known that under regulations of this type there are no incentives to reduce costs. Some authors have suggested, however, that these regulatory systems may be the result of a political equilibrium and may provide a credible commitment to yield adequate levels of investment (see for instance Armstrong and Sappington, 2005).

detrimental in terms of scale efficiency. We find that the identity of the firm is a significant determinant of technical efficiency. In particular, the operation of an internationally diversified group can be used to the benefit of consumers if regulation is properly designed. Regulatory uncertainty appears to be detrimental for technical change. Regulatory reform should take due account of scale and diversification effects, while at the same time avoiding regulatory uncertainty.

In the remainder of the paper, in Section 2 we explain the methodology used and describe the data set. In Section 3 we report the efficiency scores that result from the DEA analysis and quantify scale economies. In Section 4 we present the results of a second stage panel Tobit analysis, and in Section 5 we report the results of our analysis decomposing Malmquist indices of productivity change. Finally, Section 6 concludes and presents policy implications.

2. Methodology and data

This study investigates several dimensions of productive efficiency taking DEA measures as the starting point. We start by computing efficiency scores using the DEA technique.[4] We then use these scores to measure scale efficiency. Next, we explore the determinants of technical efficiency as measured by the DEA efficiency scores and finally we analyze the evolution of productivity components using a variety of DEA measures as inputs.

DEA is particularly well suited for regulatory practice because it requires very little technological information, allowing for a flexible non-parametric modelling of efficiency measures that can be used as benchmarks. Several authors have used this methodology to study productive efficiency in other regulated sectors – for instance Resende (2000) in telecommunications and Affuso *et al*. (2002) and Kennedy and Smith (2004) in railways.

The DEA methodology calculates an efficiency frontier for a set of units (vehicle inspection stations in our case), as well as the distance to the frontier for each unit.[5] This distance (efficiency score) between observed inspection stations and the most efficient similar stations gives a measure of the radial reduction in inputs that could be achieved for a given measure of

[4] For a more detailed explanation of this technique and a review of some of its applications, see Murillo-Zamorano (2004).

[5] It does so by using linear programming techniques as opposed to parametric techniques. DEA has the advantage of being very flexible, as it does not require any functional assumptions on production technologies or any assumption on the distribution of statistical errors.

output. The differences in efficiency scores show the potential in terms of technical efficiency of introducing some form of incentive regulation or of progressing towards liberalization. We concentrate on the input-oriented DEA model that takes output as given; this is consistent with efficiency measurement[6] in regulated sectors since the units' managers in these sectors may decide on parts of the inputs but not on the outputs.

One can compute the Constant Returns to Scale (CRS, hereafter) efficiency scores, where it is assumed that all units operate at their optimal scale so that a unit can be compared in terms of efficiency to any other unit, and where differences in efficiency have nothing to do with scale. However, in many settings this situation may not be realistic. In this case, a Variable Returns to Scale (VRS, hereafter) DEA analysis is recommended. The latter adds a convexity constraint on the CRS formulation. The usefulness of convexity is to ensure that any unit is compared to another one that is similar in size.

In the DEA with 1 output and 2 inputs under a CRS assumption, if there are *N* units whose efficiency we want to compare, the relative efficiency of unit *i* is obtained by solving the following linear programming problem:

$$\underset{\lambda}{Min}\,\theta$$

$$s.t. \quad -y_i + \mathbf{y}\boldsymbol{\lambda} \geq 0$$

$$\theta x_{1i} - \mathbf{x_1}\boldsymbol{\lambda} \geq 0$$

$$\theta x_{2i} - \mathbf{x_2}\boldsymbol{\lambda} \geq 0$$

$$\boldsymbol{\lambda} \geq 0$$

where $\boldsymbol{\lambda}$ is a vector of *N* constants, $\mathbf{y}$ is the vector of *N* observations of outputs, $\mathbf{x_1}$ and $\mathbf{x_2}$ are the vectors of observations of the input quantities, and θ is a scalar smaller than or equal to 1 that measures the relative efficiency for unit *i*.

[6] However, it should be clear that the technique we use abstracts from allocative efficiency issues and it is aimed at technical efficiency, ignoring the role that prices may have.

This problem is to be repeated for all units in the sample. When the problem is solved for all units, those with $\theta = 1$ form part of the frontier and the values of the $\boldsymbol{\lambda}$ vector for each unit form a "virtual unit" that is on the frontier, built from one or some of the units that lie on the frontier (called reference units) and from the values of $\boldsymbol{\lambda}$. The θ value that one obtains for each unit is the index of efficiency of that unit. There is a single frontier for all the units of the sample (which implies that the units acting as reference when solving the problem of the *j* unit have θ=1 when their own problem is solved), but the values of θ and $\boldsymbol{\lambda}$ (and therefore the virtual units to which each real unit is projected in the frontier) are specific for each unit.

Given the set of units under analysis, it is possible to quantify the average technical efficiency as the average of the θ values found for the different units. This average technical efficiency indicates the quantity of physical resources that can be saved (and therefore reallocated to other purposes, including an output increase in the same sector or in other activities) as a percentage of the resources that are used to produce a given output level.

The problem of constraining the values of the $\boldsymbol{\lambda}$ vector just to be greater than zero is that these values may be arbitrarily high and in consequence we may be comparing real units with reference units of very different sizes. The DEA of 1 output and 2 inputs with VRS, like the one we use in this paper, avoids this problem by adding the constraint that the sum of the constants has to be equal to 1: $\mathbf{e}'\boldsymbol{\lambda} = 1$, where **e** is a vector of ones. Restricting $\boldsymbol{\lambda}$ to adding up to 1 prevents the evaluated unit from being compared with one that is very far away in the input space; in this case, if $\boldsymbol{\lambda}$ is high, the radial projection of the evaluated unit lies far from the reference unit. The parameters θ for each unit obtained as the solution to the problem with this constraint are the indices of technical efficiency with VRS.

It is possible to measure the degree by which firms operate at the efficient scale by calculating the ratio between the efficiency scores obtained under the CRS assumption and those obtained with VRS. If the resulting indexes are identical, the unit operates with 100% scale efficiency, obtaining a value of 1 in the index of scale efficiency.

All efficiency scores reported in our exercise (including those quantifying scale economies) are calculated using a sequential frontier. This means that each observation for a given year is compared to all other observations in the same year and to observations in previous years. This way we avoid the possibility of "technical regress".[7] An alternative would be to compute yearly frontiers, so that each observation is compared only to contemporaneous observations, but that would assume that in this sector operators "forget" about practices in the previous year. Since the identity of the firms did not change over the years in our sample, we prefer a sequential frontier. However, we also computed the same scores with a contemporaneous frontier; the results are very similar, with correlations between scores higher than 96% (see Table A3 in the appendix).

In the second stage of the exercise, we use panel Tobit regressions to compute the determinants of the efficiency scores found. Coelli *et al.* (2005) suggest the use of a number of variables to assess the likely determinants of efficiency scores. Although several techniques are available, they recommend the Tobit procedure (especially when there are categorical variables) to regress the efficiency scores to a battery of variables that may explain relative technical efficiencies. We are interested in regulation, location, ownership and other control variables as determinants of technical efficiency. The reason for the use of the Tobit regression technique is that efficiency scores are bounded between zero and one and a sub-set of the sample may be accumulated into the 1 value (the efficient units). In this case, Tobit regressions offer the best methodology (see Resende, 2000; Pollitt, 1996; Dusansky and Wilson, 1994).[8]

Efficiency scores computed with DEA can also be used to decompose productivity change in measures such as the Malmquist index. There are several productivity index decompositions in the literature, and there is a lively controversy on the suitability of different decompositions for different purposes. We use the Färe *et al*. (1994) Malmquist decomposition (FGM, hereafter), which decomposes a productivity measure based on the geometric mean of two productivity measures, each taking one of two years as a benchmark. This decomposition is as follows:

$$FGM = \left[\frac{D_c^s(x_t, y_t)}{D_c^t(x_t, y_t)} \cdot \frac{D_c^s(x_s, y_s)}{D_c^t(x_s, y_s)}\right]^{\frac{1}{2}} \cdot \frac{D_v^t(x_t, y_t)}{D_v^s(x_s, y_s)} \cdot \frac{D_c^t(x_t, y_t)/D_v^t(x_t, y_t)}{D_c^s(x_s, y_s)/D_v^s(x_s, y_s)},$$

where the first term (inside the square brackets) measures technical change, the second measures technical efficiency change, and the third measures scale efficiency change between two time periods *s* and *t*, such that *s*<*t*. The measure $D_c^s(x_t, y_t)$ is the distance of an observation (of input vector and output vector) in period *t* to the CRS frontier in period *s*. If

[7] See, for instance, Shestalova (2003).

[8] For a detailed explanation of the Tobit methodology see Greene (2002).

instead of sub-index *c* we take sub-index *v* then it is the distance to the VRS frontier. We measure these distances using the DEA scores previously calculated.

The technical efficiency change measure in FGM is the same as in the Ray and Desli (1997) geometric mean decomposition. Both formulae decompose a CRS Malmquist index of productivity change (the ratio of distances to a common CRS frontier of two observations of the same unit in different time periods). The Ray and Desli index is equivalent, in the case of one output, to the generalized Malmquist index decomposition of Grifell and Lovell (1999). The FGM scale term gives a measure of the change in scale efficiency, but the scale measure in the Ray and Desli index is only a measure of scale change, not of scale efficiency change. FGM measures technical change as if the frontier were CRS, but this may not matter if the technical change is small, as it is in our case.

In our empirical exercise, the units are the different stations that perform vehicle inspections in Catalonia (Spain) under concession contracts granted by the Regional Government. All the stations belong to 3 firms (called α, β and γ for confidentiality reasons). Two of these firms are subsidiaries of the same multinational group. We have named each station by its location in the four Catalan provinces (B = Barcelona, G = Girona, L = Lleida and T = Tarragona).[9] We use data for two inputs (a unit of labour and inspection lines per station) and a measure of output (vehicles inspected) for 38 units between 2000 and 2004. The main data source is the Department of Industry of the Catalan Autonomous Government (*Generalitat de Catalunya*). We next define and describe the measures of inputs and output used.

A) *Inputs*

The first input used is the number of operating lines available in each station. Operating lines are the corridors where vehicles are positioned for the inspection of brakes, suspension, emissions and engine. Each line replicates the others in size and number and quality of machinery, and determines (together with the labour input) the amount of inspections that a station can perform per unit of time. This variable reflects the fixed capital of each station that is directly involved in inspection activities.

The second input is labour. It is a weighted estimate of the labour engaged in inspection activities in each station. Hence, we assign weights to the 6 categories of workers a station can have. The categories are: manager of the station, team chief, mechanic, assistant mechanic,

[9] Table A1 in the appendix presents a summary of statistics by province.

environment control mechanic and support staff (not directly involved in inspection activities). We assign weights to each category of worker depending on his or her direct involvement in inspection activities, obtaining an accurate measure of the labour input operating in each station. Moreover, given that some stations work all day (in two shifts: morning and afternoon) and other stations do not (just one shift), we have calculated our labour input per week accounting for the fact that a station that works all day is open 80 hours a week and the others only 40 hours a week. This procedure is the one used by the regulator (the Catalan government) to keep a record of the labour involved in the concessions.

B) *Output*

As an output measure we use the number of inspections per week performed by each station. We obtained data from the regulator of the total number of inspections per year, calculating its weekly equivalent to have a measure consistent with the labour input. Quality standards of vehicle inspections are set by the regulator and strictly enforced, and so quality may be assumed to be homogeneous across units.

3. Technical and scale efficiency scores

Table 1 presents the summary statistics of the estimated technical efficiency scores assuming CRS and VRS, and the scale efficiency scores. The complete results (by inspection units) can be found in the appendix (see Table A2).

Table 1: Summary statistics for the efficiency scores.

CRS	**2000**	**2001**	**2002**	**2003**	**2004**	**Average**
N	38	38	38	38	38	-.-
Average efficiency	61.7	60.6	61.8	62.2	61.9	61.6
Standard deviation	25.39	26.23	25.86	23.15	23.03	24.7
Efficient units	3	2	1	0	0	-.-
VRS	**2000**	**2001**	**2002**	**2003**	**2004**	**Average**
N	38	38	38	38	38	-.-
Average efficiency	90.6	86.0	86.6	86.1	85.5	86.9
Standard deviation	10.8	15.2	14.5	12.6	13.2	10.8
Efficient units	18	16	15	13	13	-.-
Scale efficiency	**2000**	**2001**	**2002**	**2003**	**2004**	**Average**
N	38	38	38	38	38	-.-
Average Scale Efficiency	69.4	73.2	73.9	74.9	75.0	73.3
Standard deviation	28.05	30.96	30.57	29.57	29.21	29.67
Scale efficient units	3	2	1	0	0	-.-

Source: Own elaborations. Note: scale efficiency is calculated as TE_{CRS}/TE_{VRS}, where TE refers to technical efficiency. Scores calculated using a sequential frontier.

In general terms, we see that the average technical efficiency for the whole period increased slightly (and its standard deviation decreased) for the CRS case, and decreased between 2000 and 2004 for the VRS estimates. The VRS efficiency scores show higher average values than the CRS scores, which is consistent with the fact that VRS compares each unit only with units of similar size. On average, productive units are 13.1% from the efficient frontier and, therefore, there is room for achieving efficiency gains in the vehicle inspection sector. If we take the last year of the sample, in 2004 the technical inefficiency relative to the sample frontier on average was 14.5%,[10] meaning that 14.5% less physical resources could be used to achieve the same output level.

Table 1 also shows the summary statistics for the scale efficiency scores of the units in the sample, that is, the CRS technical efficiency scores divided by the VRS technical efficiency scores (see Coelli *et al.*, 2005). Average scale efficiency is 73.3%. If we take the smallest station with the highest average scale efficiency in the period 2000-2004 in the provinces of Girona (0.95), Lleida (0.96) and Tarragona (0.95), they performed an average of 56,451; 53,815 and 49,580 inspections per year respectively. The scale efficiency of stations in the province of Barcelona outside its metropolitan area is quite similar:[11] they have scale efficiency scores close to 1 and they have a smaller scale, with fewer annual inspections performed than units in the Barcelona metropolitan area.

On average, for the period 2000-2004, the station that recorded most inspections was located in the metropolitan area of Barcelona, performing 96,184 inspections per year. Stations performing above 50,000 inspections operated close to an optimal scale. We confirmed these results by repeating the computation of all efficiency scores using non-decreasing returns to scale technology, which yielded results very similar to those obtained using VRS technology.[12] This means that the true VRS technology for the sample units is non-decreasing returns to scale: medium and large stations perform at an optimal scale, but small stations do not.

This implies that, for instance, stations performing the highest number of inspections in the sample can lose about half of their customers and still operate very close to the optimal scale. This suggests that new stations (a likely effect of liberalization) that capture customers from existing stations in densely populated areas are to a large extent compatible with scale efficiency. Moreover, in Table 2 we show that inspection units in the territory with the lowest population density (Lleida) are the ones that clearly operated at a suboptimal scale. We conclude that economies of scale are certainly present in vehicle inspections, but are exhausted for stations in most of the territories in the sample.

[10] As Table A2 (in the appendix) shows, some vehicle inspection stations have very low efficiency scores. Hence, taken individually it seems that there is room for some dramatic efficiency gains. Data on inputs and output are not shown but are available upon request.
[11] The Barcelona province is divided into two very different regions: the urban Barcelona Metropolitan Area, with two thirds of the overall Catalan population, and the rest of the province.
[12] We have not included these results for reasons of space, but they are available upon request.

Table 2: Scale efficiency per province.

	2000	2001	2002	2003	2004	Average
Barcelona	86.4	91.3	91.7	92.3	93.0	91.0
Girona	66.8	72.7	74.0	74.3	71.6	71.9
Lleida	34.4	34.3	35.1	36.5	37.0	35.5
Tarragona	67.5	71.0	71.9	75.0	76.2	72.3

Source: Own elaborations. See Note to table 1.

4. The determinants of efficiency scores and the value of firm international diversification

In this section we perform a second stage panel Tobit regression, using, as endogenous variable, a transformation of the VRS efficiency scores computed in the previous section, in particular we use 1-VRS. In this way the endogenous variable is censored at the 0 value, as required by the Tobit technique, and if an explanatory variable has a (significant) negative impact in the regression it means that it is a significant determinant of relative efficiency (see Resende, 2000). Next we present the variables considered, *a priori*, as possible determinants of the efficiency scores observed.

It must be stressed that all units in our sample operated under the same regulatory regime, but that the regime became tighter and more subject to regulatory uncertainty in the last years of the sample period. We capture this effect by introducing year dummies as proxies for the evolution of regulation. More precisely, we introduce a variable (*DV-0304*) that takes value 0 for the years 2000, 2001 and 2002, and value 1 for the years 2003 and 2004. In 2002 there was the last tariff change in Catalonia for the sample years.

We capture location characteristics by measuring the population density (*Density)*, the GDP per capita (*GDPpc*), and the economic activity (*GDP*) of the territories where the vehicle inspection units operate.[13] We also use a dummy for the Barcelona Metropolitan Area (*DV-Metropolitan area*), which is 0 if the station is not in this area, and a control variable that accounts for the number of years that a vehicle inspection station has been operating (*Years Open*).

We capture ownership differences in two ways: by differentiating stations where the building is owned from those where the building is rented, and by classifying stations by the operating firm

[13] The territorial unit used in this case is smaller than the province (to have some variation across units given that we have only 4 Catalan provinces). Specifically, we use the "Comarca", which in Spain corresponds roughly to the *shire* territorial division in UK.

that manages them. In the first case, we use the variable *DV-property*, which is 0 if the station is not owned by operating firms or the regional government but by a third party, and 1 otherwise.

The second way of capturing ownership is very important in our case because vehicle inspection stations in Catalonia belong to three different firms: two of them (firms α and β) manage 85% of the stations and belong to a diversified multinational group (which operates in a number of regulated sectors across the world), while the other (firm γ) is a focused small firm that manages only 15% of the stations in the sample and has no other economic activity. If there are significant differences in technical efficiency between firms (α and β with respect to γ), this may indicate that the first two firms enjoy economies of scope or diversification and scale economies at the company group level. To capture these effects, we construct a dummy variable (*DV-Firm*) that is 0 for firm γ and 1 for firms α and β.

Usually, studies of technical efficiency are used to test the hypothesis that privately-owned firms are more efficient than state-owned firms.[14] However, the distinction between privately-owned and state-owned is by no means the only potentially interesting difference across firms. As explained, the firms operating the concessions in Catalonia differ widely from each other from the point of view of ownership, and we would expect these differences to have an impact on efficiency scores.

The multinational group which operates the stations in the most densely populated territories in Catalonia also inspects vehicles in 7 regions in the rest of Spain, and has investments in 24 different countries, including the US and China.[15] We can therefore test hypotheses concerning scope and scale efficiency at the firm level, and to what extent potential scale and scope economies are captured by a regional regulatory system that applies only to a particular segment of a diversified multi-national organization. Under a cost-plus regulatory regime, diversified regulated firms have an incentive to allocate the worst inputs (managers, other workers, machinery) to the regulated segments. Under an incentive-based regulatory system, however, firms have no incentive to do so.[16]

The results from the second stage panel Tobit estimation are presented in Table 3. Observe that the variables that are significant in the panel Tobit regressions are the number of years open and the identity of the firm. Technical efficiency appears to be significantly higher in stations

[14] See Pollitt (1996).

[15] This multinational group expanded during the years of the study. In 2004, the group acquired the privatized vehicle inspection concessions in Denmark and the certification division of *Soluziona*, a division of energy firm *Unión Fenosa*. Moreover, executives of the group repeatedly stated that they wanted to base their expansion on the inspection division.

[16] On the relationship between regulation and diversification, see Armstrong and Sappington (2005) and references therein.

belonging to a diversified group than in stations belonging to a firm which is not diversified but specializes in vehicle inspection and manages around 15% of the inspection units in Catalonia.[17]

Table 3: Random Effects Tobit model. VRS scores.

	Model 1	*Model2*	*Model 3*	*Model 4*
Constant	-3.602 (-0.573)	-3.526 (-0.561)	-3.857 (-0.633)	-6.097 (-0.748)
Years Opened	1.408 (3.412)***	1.422 (3.444)***	1.582 (4.263)***	1.426 (3.421)***
DV-Property	3.579 (1.046)	3.297 (0.901)	0.612 (0.194)	4.054 (1.117)
DV-Firm	-14.113 (-4.145)***	-13.904 (-3.954)***	-13.417 (-3.409)***	-13.750 (-3.668)***
D-0304	0.097 (0.069)	0.737 (0.051)	-0.463 (-0.305)	0.193 (0.136)
DV-Metropolitan area	12.295 (2.635)***	13.470 (1.908)*	4.623 (1.041)	12.299 (2.752)***
Density	--.--	-0.0013 (-0.6268)	--.--	
GDP	--.--	--.--	0.0003 (1.504)	
GDPpc	--.--	--.--	--.--	108.564 (0.570)
N	38	38	38	38
t	5	5	5	5
Sigma (v)	11.051 (23.883)***	11.016 (23.858)***	11.088 (23.698)***	10.961 (24.000)***
Sigma (u)	20.830 (9.277)***	20.721 (9.107)***	19.898 (8.430)***	21.225 (9.452)***
Log-likelihood	-507.753	-507.596	-508.481	-507.095

Notes: t-values in parenthesis. *, ** and *** indicate significance at 90, 95 and 99 percent level, respectively. Estimations performed with random individual and time effects (2-way REM model). Time span: 2000-2004. DV-property is 0 if property of the station implies a cost for the firm. DV-Firm is 0 for firm γ. DV-0304 is 0 for 2002 (last tariff change) and before. DV-Metropolitan area is 0 if the station is located in the metropolitan area of Barcelona. Control variables (Density, GDP and GDPpc) are calculated for the "comarca" at which the inspection station is located.

[17] The firm dummy variable weakly showed the opposite sign in the CRS Tobit regressions (which we do not report here), because all firms operating on a very small scale belong to the more efficient group.

The results are consistent, therefore, with scope or scale economies at the firm level. However, we cannot distinguish between these two sources of efficiency since we cannot tell whether gains in efficiency are the result of a) a diversified portfolio of activities, b) the result of a globally higher output in the vehicle inspection sector, or c) both.

5. The evolution of efficiency and regulatory uncertainty; Malmquist indices

The FGM Malmquist index decomposition described in Section 2 is presented in Table 4. This table reports the change in total factor productivity for each unit from one year to the next, and this change is decomposed into technical change (shifts in the frontier), technical efficiency change (how close to the frontier units become) and scale efficiency change (to what extent units change their size relative to the optimal scale).[18]

Table 4. Summary results for Färe et al (1994) Malmquist Index decomposition.

Index	**TC**	**TEC**	**SC**	**FGM**
2000-2001	1.01338	0.94736	1.04186	0.99961
2001-2002	1.00369	1.01033	1.01663	1.03077
2002-2003	1.00000	1.01301	1.03077	1.03718
2003-2004	1.00000	0.99228	1.00574	0.99859
Mean	1.00427	0.99075	1.02375	1.01654
Percentage change	**TC**	**TEC**	**SC**	**FGM**
2000-2001	1.34%	-5.26%	4.19%	-0.04%
2001-2002	0.37%	1.03%	1.66%	3.08%
2002-2003	0.00%	1.30%	3.08%	3.72%
2003-2004	0.00%	-0.77%	0.57%	-0.14%
Mean	0.43%	-0.93%	2.37%	1.65%

Note: TC: technical change. TEC: technical efficiency change. SC: scale efficiency change. FGM: Färe Generalized Malmquist. Source: Own elaboration. Individual scores calculated using sequential frontiers.

The main result of the decomposition is that productivity change is mostly explained by a change in scale efficiency. Interestingly, there was hardly any technical change after 2001, and there was some positive technical efficiency change between 2001 and 2003. Technical efficiency diminished overall, but the decrease was concentrated in the transition between the

[18] As mentioned above, to compute the Malmquist decomposition we used sequential frontiers. To compute the decomposition, we used the Software Package FEAR of the R programme (see Wilson, 2006).

first and the second year, when tariffs were routinely increased at the proposal of firms. We conclude that dynamic efficiency stagnated (remember that with sequential frontiers, technical change cannot be negative) and static efficiency results (relative to the yearly frontier) were worse in the years characterized by a cost-plus regime. Further research should clarify the source of this paradox, but we conjecture that it may have to do with the regulatory uncertainty in years 2003 and 2004, which we will describe next.

In September 2003, the Catalan government announced an extension of the concession contract period. Due to expire in 2006, the period was now extended until 2014. This was ahead of an election to the Catalan Parliament in November 2003, with all pre-election polls since 2001 suggesting that the opposition parties were likely to obtain a majority. These opposition parties announced that, once in office, they would reverse the extension decision on concession contracts. Although with a narrower majority than expected, the opposition left and centre-left parties won the elections in November and took office in a new coalition government in December 2003. In September 2004 the new government reversed the decision extending the concession contracts, and reinstated the original expiry date of 2006. Throughout this period tariffs remained at the same level as in 2002, when they had been raised for the last time. Hence, regulatory uncertainty (which discouraged firms from putting specific assets at risk) was accompanied by a change in the regulatory system into something more akin to a price-cap system, so that firms had an incentive to lower their operating costs.

Therefore, in 2003 and 2004 regulatory uncertainty co-existed with tighter regulation. Our conjecture is that regulatory uncertainty hurt dynamic incentives (new investments, innovation) but that the tighter regulation did not hurt as much static incentives (technical efficiency and scale efficiency), since firms had to work harder to make a profit, given that the government was refusing to increase tariffs.

6. Conclusions and policy implications

The results of this study have a number of implications both for the relationship between productive efficiency analysis and the theory of regulation and for public policy.

First, we find differences in technical efficiency between existing vehicle inspection units, implying that liberalization or incentive regulation might in fact improve productive efficiency in our sample's units. Liberalization can take the form of competition for the market or competition in the market, which has the advantage over incentive regulation that it not only has a (firm's) rent reducing effect, but also a sampling effect: the probability of more efficient firms operating in the market may be higher if competition is appropriately designed (see Armstrong and Sappington, 2005).

Second, the scale efficiency results suggest that the optimal scale is not achieved for low density territories, but stations in high density territories easily exhaust scale economies. Hence, in high density territories a greater number of smaller stations may still operate at an efficient scale. We thus show that there is scope for improving technical efficiency (which can be achieved both by liberalization and by incentive regulation) and scale efficiency (which can be achieved by liberalization).

Third, stations belonging to a large diversified group show better productive efficiency, reflecting the fact that economies of scale or scope at the firm level are captured by the current regulatory system. However, we conjecture that permitting other diversified groups to compete for the market or in the market (with some precautions in terms of safeguarding the current levels of service quality)[19] may allow for further economies to be captured. Incentive regulation has additional potential when (regional or national) regulators have less scope than (multinational) firms, because if prices do not track costs, multinational or diversified firms have less incentive for internal cost and managerial cross subsidies (allocating fixed costs or less skilled managers to cost-plus regulated segments).

Fourth, the regulatory uncertainty in years 2003 and 2004 may be the reason for the absence of technical progress in those years in our sample of inspection units. With the frontier methods used in this paper it is easier to measure the relative inefficiencies of firms than to find the reasons for the differences in efficiency levels. However, knowledge of the details of the regulatory system and its history will help to draw useful policy lessons. In this case, we believe that significant savings could be made in future years if liberalization (or some form of incentive regulation such as yardstick competition) is introduced. This is recommended when firms have superior technological information and make non-verifiable cost reductions. With explicit and transparent incentive regulation, the regulatory system could take more advantage of the diversified nature of multi-national firms, which is already providing promising results in terms of technical efficiency. Incentive regulation would probably be accompanied by an

[19] With liberalization or incentive regulation, quality (so far high) becomes a concern. However, with multinationals, international and intertemporal reputation may exert some control on incentives to lower quality.

increased concern for product quality, which, according to qualitative appreciations by industry participants, is currently considered to be high. Liberalization can then be used to attract other (strong and efficient) diversified industry groups.[20]

If policy makers decide in favour of liberalization, they must address issues related not only to the quality of service provision but also to universal service (prices equal to or above average costs in some regions may be below the average cost of existing production levels in regions with a low population density).

However, our results should be interpreted with care. Frontier methods such as DEA reveal relative efficiencies. It may well be that, when compared with similar units in other jurisdictions, the results may differ. Future research should perform comparisons of this kind, and then differences in regulatory systems could be introduced in our Tobit regressions to draw lessons for the costs and benefits of different rules of the game.

Future research may also address more fully a number of issues raised here, all of them related to the fact that (at least part of) firms operating concessions belong to multinational groups and operate in a number of local jurisdictions. This research should more explicitly explore the connection between the analysis of reform in this industry and the literature on the regulation of multi-nationals, the literature on multi-market contact, and the interaction between regulatory federalism, capture and the political cycle.

[20] One of these other diversified multi-national firms sued the Catalan government in 2003 for the extension of the concession period (see section 5). This reveals another potential benefit of competition, which to our knowledge remains unexplored in the literature: when there are multi-nationals operating in some jurisdictions but not in others, competition for the rules puts pressure on potentially captured local regulators.

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Data Appendix

Table A1: Summary statistics. Averages per province

Barcelona	**2000**	**2001**	**2002**	**2003**	**2004**
Number of stations	18	18	18	18	18
Operating lines	2	2	2	2	2
Employment per week	160	175	175	174	173
Output per week	1059	1044	1054	1054	1047
Girona	**2000**	**2001**	**2002**	**2003**	**2004**
Number of stations	7	7	7	7	7
Operating lines	2	2	2	2	2
Employment per week	122	141	141	142	134
Output per week	619	661	685	690	592
Lleida	**2000**	**2001**	**2002**	**2003**	**2004**
Number of stations	8	8	8	8	8
Operating lines	1	1	1	1	1
Employment per week	74	78	78	76	76
Output per week	242	244	258	267	273
Tarragona	**2000**	**2001**	**2002**	**2003**	**2004**
Number of stations	5	5	5	5	5
Operating lines	2	1	1	2	2
Employment per week	117	129	129	132	132
Output per week	581	603	624	666	683
TOTAL	**2000**	**2001**	**2002**	**2003**	**2004**
Number of stations	38	38	38	38	38
Operating lines	2	2	2	2	2
Employment per week	129	142	142	142	140
Output per week	743	747	762	770	753

Source: Own elaboration.

Table A2: Efficiency scores by unit.

	CRS efficiency scores					**VRS efficiency scores**					**Scale efficiency scores**				
	2000	**2001**	**2002**	**2003**	**2004**	**2000**	**2001**	**2002**	**2003**	**2004**	**2000**	**2001**	**2002**	**2003**	**2004**
B1	100.0	84.4	80.0	87.4	84.1	100.0	84.9	80.8	87.9	84.7	100.0	99.4	98.9	99.4	99.3
B2	100.0	98.8	95.0	73.5	79.5	100.0	99.0	95.1	73.8	82.7	100.0	99.7	99.8	99.6	96.1
B3	71.3	76.0	79.4	83.3	76.3	82.8	81.7	84.3	87.3	78.0	86.1	93.0	94.1	95.4	97.7
B4	94.9	86.3	77.1	82.8	82.7	98.7	86.4	77.2	83.2	83.2	96.1	99.8	99.9	99.5	99.4
B5	64.0	64.0	65.9	77.3	80.4	78.1	70.3	71.6	82.3	84.6	81.9	91.1	91.9	93.9	95.0
B6	96.3	90.9	87.6	78.4	79.1	100.0	91.0	87.6	78.4	79.1	96.3	99.8	100.0	100.0	100.0
B7	64.4	65.6	71.8	95.2	97.8	70.9	67.7	73.0	95.2	97.8	90.8	96.9	98.4	99.9	100.0
B8	58.2	55.5	57.7	63.8	65.5	75.1	62.6	64.2	70.7	72.0	77.6	88.7	89.8	90.2	91.0
B9	90.7	98.9	98.5	80.1	72.2	95.9	100.0	99.7	81.1	75.1	94.6	98.9	98.8	98.7	96.1
B10	82.2	68.1	64.7	79.3	77.8	91.3	69.7	66.9	79.3	77.9	90.1	97.7	96.8	99.9	99.9
B11	57.8	54.4	53.3	56.1	57.1	76.1	65.1	64.2	66.4	67.1	76.0	83.6	83.0	84.5	85.1
B12	47.0	41.1	42.2	39.8	40.6	100.0	100.0	100.0	64.6	65.2	47.0	41.1	42.2	61.5	62.2
B13	77.6	75.8	80.8	76.8	83.5	88.8	79.0	82.8	80.3	84.1	87.4	96.0	97.6	95.7	99.3
B14	85.2	71.9	98.2	74.2	76.6	91.8	72.0	99.1	75.4	77.6	92.8	99.9	99.1	98.4	98.7
B15	100.0	98.7	89.1	92.0	82.1	100.0	99.3	89.4	92.3	82.2	100.0	99.4	99.7	99.6	99.9
B16	53.6	51.4	54.0	71.8	78.1	72.7	62.9	64.9	100.0	100.0	73.7	81.7	83.3	71.8	78.1
B17	99.8	97.0	99.7	96.5	95.3	100.0	97.2	99.8	96.6	95.3	99.8	99.8	99.9	99.9	100.0
B18	45.6	49.0	50.0	73.2	75.9	69.3	63.2	64.0	100.0	100.0	65.8	77.5	78.2	73.2	75.9
G1	70.0	66.9	67.7	60.9	44.5	76.2	70.2	70.9	64.9	54.3	91.8	95.3	95.5	93.8	82.0
G2	69.3	62.8	65.9	75.0	70.7	82.7	68.4	70.8	80.1	76.8	83.8	91.8	93.1	93.7	92.1
G3	60.6	45.5	46.1	47.9	45.4	100.0	62.3	62.7	63.8	61.8	60.6	73.1	73.5	75.1	73.5
G4	22.0	23.2	24.3	23.4	23.9	100.0	100.0	100.0	100.0	100.0	22.0	23.2	24.3	23.4	23.9
G5	65.9	65.4	67.2	66.7	60.9	81.2	73.5	74.8	72.8	68.4	81.2	89.0	89.8	91.6	89.0
G6	73.9	71.1	74.7	78.9	78.3	84.3	73.2	75.9	79.5	78.9	87.7	97.2	98.5	99.3	99.2
G7	40.9	39.6	43.3	43.3	41.0	100.0	100.0	100.0	100.0	100.0	40.9	39.6	43.3	43.3	41.0
L1	70.8	100.0	100.0	70.0	72.2	79.8	100.0	100.0	74.6	76.5	88.8	100.0	100.0	93.8	94.4
L2	19.5	17.6	18.1	20.5	21.0	100.0	100.0	100.0	100.0	100.0	19.5	17.6	18.1	20.5	21.0
L3	24.9	25.4	26.7	26.3	27.2	100.0	100.0	100.0	100.0	100.0	24.9	25.4	26.7	26.3	27.2
L4	52.4	44.8	46.2	51.5	52.4	100.0	100.0	100.0	100.0	100.0	52.4	44.8	46.2	51.5	52.4
L5	31.2	27.3	28.7	31.7	30.8	100.0	100.0	100.0	100.0	100.0	31.2	27.3	28.7	31.7	30.8
L6	22.8	22.5	24.0	25.9	26.5	100.0	100.0	100.0	100.0	100.0	22.8	22.5	24.0	25.9	26.5
L7	19.7	19.6	19.8	22.7	23.5	100.0	100.0	100.0	100.0	100.0	19.7	19.6	19.8	22.7	23.5
L8	16.3	17.3	17.6	19.2	20.0	100.0	100.0	100.0	100.0	100.0	16.3	17.3	17.6	19.2	20.0

T1	79.8	100.0	97.1	86.1	87.6	90.0	100.0	100.0	87.2	88.2	88.7	100.0	97.1	98.8	99.3
T2	62.3	58.5	60.7	63.6	66.1	79.0	67.6	69.3	71.2	73.1	78.9	86.5	87.6	89.3	90.4
T3	40.2	39.7	40.8	41.8	44.3	100.0	100.0	100.0	100.0	100.0	40.2	39.7	40.8	41.8	44.3
T4	45.4	42.5	44.4	48.8	50.7	100.0	100.0	100.0	100.0	100.0	45.4	42.5	44.4	48.8	50.7
T5	67.1	86.5	89.5	78.9	79.7	79.7	100.0	100.0	82.1	82.7	84.2	86.5	89.5	96.2	96.4

Source: Own elaborations. Note: All scores obtained using sequential frontiers and an input-oriented DEA. Scale efficiency scores obtained dividing CRS efficiency scores and VRS efficiency scores (TE_{CRS}/TE_{VRS}). Individual scores calculated using sequential frontiers.

Table A3: Correlation coefficients of scores obtained with sequential and contemporaneous frontiers.

	2000	**2001**	**2002**	**2003**	**2004**
VRS	1.000	0.987	0.976	0.965	0.962
CRS	1.000	0.997	0.999	0.976	0.983

Source: Own elaborations.

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