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

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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 with a homogeneous level of quality, which is enforced by a regional regulator, between the years 2000 and 2004. The differences in efficiency scores show the potential technical efficiency benefits 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 a 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 into the most densely populated territories (a likely effect of some form of liberalization) would not be detrimental in terms of scale efficiency. The firm's identity seems to be a determinant of the distance to the efficiency frontier. 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.

Key words: Productive Efficiency, Regulatory Reform, Vehicle Inspections.

JEL Classification: C61, L51, R38.

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In this study we perform an exercise in productive efficiency benchmarking, using a new data set of inputs and outputs in the vehicle inspection sector. We also derive some implications about the determinants of productive efficiency and about regulatory reform. 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 inspections. In some jurisdictions, such as the UK and 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). 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 in 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 2003, the central legislators introduced a system of authorizations to replace concessions in order to boost liberalization, 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, but a new regional law was still being drafted by mid 2007[2].

Using data for the Spanish regions in 2005, kindly provided by the Spanish Ministry of Industry, we can report that most regions still operated vehicle inspec-

(1) See Hubbard (1997, 1999, 2002), Merrell *et al.* (1999), Sutter and Poitras (2002) and Poitras and Sutter (2002). These articles dispute that compulsory vehicle inspections are necessary to obtain accident or emissions levels that are closer to the social welfare maximizing levels, by comparing states with and without compulsory inspections.

(2) A new law was finally approved in 2008, setting an upper bound of 50% for market shares and partially moving towards an authorization regime.

tions through a concessions regime. In three regions (Andalusia, Asturias and Extremadura) the public sector directly operated all or part of the vehicle inspections. Prices and the percentage of rejected inspections varied widely across regions. The lowest price per inspection was €23.02 in Extremadura and the highest was €41.93 in Valencia. The average price was €30.73, and the price in Catalonia was €30.22 (this nominal price in Catalonia had been the same since 2002). The region with the lowest number of rejected inspections was Madrid with 9% and the region with the highest number of rejected inspections was Asturias with 35%. The Spanish average across regions was 21% and the rejection ratio in Catalonia was also 21%.

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[3], which has been increasing globally. 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 multinational 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, and 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 their expenditure to vehicle inspections: in our sample units, about €30 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 inspections are a steady source of cash for firms operating in a sector in which demand is growing. We thus conjecture that firms have a far greater influence in policy design and implementation than consumers. Therefore, there is high potential for regulatory capture[4]. The complexity

(3) 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.

(4) 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

of the interaction between firms and policy makers increases with the presence of multinational operators. How to design national or even (in decentralized countries like Spain) regional regulation to benefit consumers when some of potential firms are powerful multinationals is an important question.

In this study, we use the Data Envelopment Analysis (DEA, hereafter) methodology to measure productive efficiency for 38 vehicle inspection stations or units for the period 2000-2004 in Catalonia (Spain). These units were under a concession regime with centrally enforced homogeneous quality, in the sense that the regulator (the regional government) controlled the service quality standards across units (this is called a centralized system in the vehicle inspection industry, like those of Ireland and Chile, as opposed to a decentralized system like that of the UK, France or some US states, where units have much more autonomy and flexibility). We further control for quality by calculating the efficiency scores for the years where we have some quality data. The quality-adjusted efficiency scores do not show systematically different results.

As far as we know, only two other DEA have been applied to vehicle inspections in the economics literature. Both use samples of publicly-owned vehicle inspection 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%. This author, as we do in this paper, 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 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 27.0% (28.8% 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 detrimental in terms of scale efficiency. With the efficiency scores obtained we also perform a second-stage analysis of the likely determinants of these scores. Using, among others, bootstrap techniques proposed by Simar and Wilson (2007) to avoid the likely bias caused by the fact that efficiency scores depend on all observed inputs and outputs (and, hence, are not independently distributed), we analyze to what extent the nature of the operating firm may be a significant determinant of firm efficiency. In particular, the operation of an internationally diversified group can be used to the benefit of consumers if regulation is properly designed. We finally report and decompose a

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)].

Malmquist index to quantify the sources of productivity change, observing that technical change was not positive for most of our sample years. We conjecture that regulatory uncertainty was detrimental for technical change. Regulatory reform should take due account of scale and diversification effects, while at the same time avoiding regulatory uncertainty. These results should be taken with care because the sample corresponds to one single region in a short period of time and the inputs are measured in a broad way. However, they illustrate the potential for using productive efficiency analysis to guide regulatory reform.

In the remainder of the paper, in Section 1 we explain the methodology used and describe the data set. In Section 2 we report the efficiency scores that result from the DEA and quantify scale economies. In Section 3 we present the determinants of efficiency scores in a second-stage analysis using bootstrap techniques and, in Section 4 we report the results of our analysis decomposing a Malmquist index of productivity change. Finally, Section 5 concludes and presents policy implications.

1. Methodology and data

This study investigates several dimensions of productive efficiency taking the DEA results as its starting point. We begin by computing efficiency scores using the DEA technique[5]. 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 Malmquist index, which is also based on the DEA results.

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 (or related techniques) to study productive efficiency in other regulated sectors –for instance, Resende (2000) in telecommunications, Yatchew (2000) in electricity 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[6]. This distance (efficiency score) between observed inspection stations and the most efficient similar stations gives a measure of the reduction in inputs that could be achieved for a given measure of 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 effi-

(5) For a more detailed explanation of this technique and a review of some of its applications, see Murillo-Zamorano (2004). For examples of applications of productivity analysis in different industries, see Glass *et al.* (1995) and Coelli (1996).

(6) 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.

ciency measurement[7] in regulated sectors since the units' managers in these sectors have more discretion to make decisions on input levels than on output levels.

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 is recommended. This adds a convexity constraint to the CRS formulation. Convexity is useful to ensure that any unit is compared to another one that is similar in size (see, among many others, Coelli *et al*., 2005, for technical details on the DEA technique).

It is possible to measure the degree to 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"[8]. 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 92% (see Table A3 in the appendix).

In the second stage of the exercise, we compute the determinants of the efficiency scores found. In this second stage we are interested in regulation, location, ownership and other control variables as possible determinants of technical efficiency. However, there are two main problems when analysing the determinants of efficiency scores. First, the type of specification to be estimated. Second, efficiency scores are not independent and identically distributed (iid). In other words, results of the second stage regression can be biased because efficiency scores obtained in the first stage depend on all observed inputs (even the exogenous variables introduced in this second stage) and outputs [see Cordero *et al*. (2008)].

Concerning the first problem, the Tobit procedure is widely used to regress the efficiency scores on a battery of variables that may explain relative technical efficiencies. The reason for the use of this 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)[9]. However, as pointed out by Puig-Junoy

(7) However, the technique we use abstracts from allocative efficiency issues and is aimed at technical efficiency, ignoring the role that prices may have.

(8) See, for instance, Tulkens and Vanden Eeckaut (1995).

(9) Some applications that use the Tobit procedure in a second-stage estimation are, for instance, Resende (2000); Pollitt (1996) or Dusansky and Wilson (1994).

(1998), the efficiency scores obtained with DEA do not fit the theory of sampling censoring required for Tobit models[10] or, in other words, "the accumulation of sample observations at the highest level of efficiency is intrinsic to the model". Therefore, the Tobit estimation is not completely adequate and we use a logit transformation of the efficiency scores that allows us to use traditional OLS techniques. To solve the second problem, we apply bootstrap techniques proposed by Simar and Wilson (2007) to avoid the bias problem inherent in the use of efficiency scores as the dependent variable in the second-stage regressions. As a final robustness exercise in this second stage, we divide the sample into two sub-samples (one for the vehicle inspection units belonging to a multinational group and the other for the units belonging to a small local firm) to analyze whether the efficiency scores systematically differ across ownership types.

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 used both the Färe *et al.* (1994) Malmquist decomposition (FGNZ, hereafter) and the Ray and Desli (1997) decomposition (RD, hereafter). The FGNZ 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:

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

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, 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 FGNZ is the same as in the RD 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 RD index is equivalent, in the case of one output, to the generalized Malmquist index decomposition of Grifell-Tatjé and Lovell (1999):

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

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

(10) The Tobit model is based on normally distributed latent variables.

The FGNZ scale term gives a measure of the change in scale efficiency, but the scale measure in the RD index is only a measure of scale change, not of scale efficiency change. FGNZ measures technical change as if the frontier were CRS[11].

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[12]. We have named each station by its location in the four Catalan provinces (B = Barcelona, G = Girona, L = Lleida and T = Tarragona)[13]. 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. Inspection lines are treated as a fixed input over which the managers have no discretion. This way we avoid interpreting efficiency scores as the potential for radial reduction in all inputs when operating lines cannot be fractioned. The main data source is the Department of Industry of the Catalan Autonomous Government (*Generalitat de Catalunya*). Below, we define and describe the measures of inputs and output used.

A) Inputs

The first input is labour. It is a weighted estimate of the labour engaged in inspection activities in each station. The Catalan Autonomous Government assigns weights to the 6 categories of workers a station can have. The categories are: manager of the station, team chief, mechanic, assistant mechanic, environment control mechanic and support staff (not directly involved in inspection activities). These weights (different for each station) are assigned 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. Given that the skill mix can be different across units, it is highly desirable to use a measure that can distinguish among different types of labour.

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 to account for the labour input is the one used by the regulator (the Catalan government) to keep a record of the labour involved in the concessions.

The second 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 quantity of inspections that a station can perform per unit of

(11) In the section 4, we present the full set of results for the RD decomposition. Nevertheless, the main conclusions drawn from the Malmquist decomposition hold if we use the FGNZ decomposition instead. For a complete review of pros and cons of the various Malmquist productivity index decompositions, see Zofio (2007).

(12) The 3 firms are (not in order): ECA, RVSA and ECA-ITEUVE, where ECA and ECA-ITEUVE belong to the multinational group Applus+.

(13) Table A1 in the appendix presents a summary of statistics by province.

time. This variable reflects the fixed capital of each station that is directly involved in inspection activities[14].

Note that, as mentioned, we treat operating lines as a fixed, non-controllable input. Therefore, to compute the efficiency scores we make use of one-stage models proposed by Banker and Morey (1986) where non-controllable inputs are included directly to estimate efficiency scores with an additional restriction in the formulation of the standard DEA program. Hence, the Banker and Morey (1986) approach considers a subset of the production possibility set obtained by fixing the non-discretionary inputs (operating lines in our case) at their current values. To interpret the results, we have to take into account that this model does not attempt to reduce all inputs equiproportionally, but only the input that can be directly controlled by managers (labour in our case).

B) Output

As an output measure, we use the number of inspections per week performed by each station. We obtained data from the regulator about the total number of inspections per year, calculating its weekly equivalent in order to have a measure consistent with the labour input.

2. Technical and scale efficiency scores

2.1. Technical efficiency

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

In general terms, we see that the average technical efficiency for the whole period slightly decreased (its standard deviation also decreased) for both the CRS and the VRS case. 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, inefficient units have 27.0% less efficiency than units on the efficient frontier and, therefore, there is room for achieving efficiency gains in the Catalan 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 28.8%[15], meaning that 28.8% less labour input resources (for a given level of operating lines) could be used to achieve the same output level.

2.2. Scale efficiency

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 Banker *et al.*, 1984). Average scale efficiency is 74.1%. If we take the smallest station with the highest average scale efficien-

(14) Unfortunately, we could not have access to more detailed or divisible capital input data.

(15) 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.

Table 1: SUMMARY STATISTICS FOR THE EFFICIENCY SCORES

CRS	2000	2001	2002	2003	2004	Average
N	38	38	38	38	38	–
Average efficiency	56.0	54.3	55.6	55.4	55.1	55.3
Standard deviation	25.6	26.9	26.6	22.2	22.0	24.7
Efficient units	3	2	1	0	0	–
VRS	**2000**	**2001**	**2002**	**2003**	**2004**	**Average**
N	38	38	38	38	38	–
Average efficiency	80.6	70.2	71.3	71.6	71.2	73.0
Standard deviation	13.5	16.6	15.9	11.9	12.1	14.0
Efficient units	7	4	2	1	1	–
Scale efficiency	**2000**	**2001**	**2002**	**2003**	**2004**	**Average**
N	38	38	38	38	38	–
Average Scale Efficiency	68.7	74.7	75.4	76.0	76.0	74.1
Standard deviation	26.2	24.8	24.7	23.8	23.4	24.6
Scale efficient units	4	6	5	3	2	–

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

Source: Own elaboration.

cy in the period 2000-2004 in the provinces of Girona (0.90), Lleida (0.93) and Tarragona (0.95), they performed an average of 51,052, 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[16]: 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[17]. 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.

(16) 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.

(17) We have not included these results for reasons of space, but they are available upon request.

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 sub-optimal 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.

Table 2: SCALE EFFICIENCY PER PROVINCE

	2000	2001	2002	2003	2004	Average
Barcelona	85.2	88.5	89.1	90.7	91.3	89.0
Girona	65.0	72.9	74.1	75.0	72.6	71.9
Lleida	36.9	43.9	44.6	44.0	44.5	42.8
Tarragona	65.2	76.3	77.3	75.2	76.1	74.0

See Note to Table 1.

Source: Own elaboration.

2.3. Quality issues

Quality issues could distort the interpretation of efficiency scores [see Sappington (2005)] because inspection units could reduce costs by reducing quality, scoring high in technical efficiency if output is not quality-adjusted. However, three pieces of evidence make us quite confident that our efficiency scores are not distorted by quality issues.

The first piece of evidence is that, as argued above, the regional regulator enforces quality (under technical standards fixed at the Spanish level). Officials in the Catalan Government Department of Industry try to make sure that inspections follow the same procedures in all Catalan stations. The standards are enforced by random inspections carried out by civil servants. This is what, in the language of this industry, is called a centralized inspection system, meaning that the regulator enforces a common set of inspection procedures for all units. This is the system prevalent in jurisdictions such as the Spanish regions, Chile and Ireland. Other systems are decentralized, in the sense that inspection units have much more discretion in how they perform the vehicle inspections. Thus, in the inspection units of our sample, under the "centralized" Catalan system, we would expect a homogeneous level of quality.

The other two pieces of evidence use, as a proxy for quality, data on the percentage of rejected inspections, that is, as a measure of the toughness of inspections. Of course, there are many other quality dimensions in practice (customer attention, inspectors' skills, etc.), but it is very difficult to obtain data for these other dimensions. We do, however, have data (for 2003 and 2004, see Table 3) on the percentage of rejected inspections and we exploit this data.

Table 3: AVERAGE PERCENTAGE OF REJECTED INSPECTIONS PER PROVINCE

	Barcelona	Tarragona	Lleida	Girona
2003	21%	22%	22%	25%
2004	21%	23%	22%	25%

Source: Department of Industry (*Generalitat de Catalunya*).

It could be argued that an easy way to carry out inspections quickly (and to attract drivers/users) for a given level of inputs would be just to rubber stamp inspection documents without rejecting any vehicle. Rejections are, then, a positive measure of quality.

The second piece of evidence comes from comparing the rejection data in the Catalan provinces in 2003 and 2004 with the rejection data in the Spanish regions for 2005. Quality (as proxied by the percentage of rejected inspections) variation in Catalonia as summarized in Table 3 is much lower than the variation across Spanish regions (with slightly different regulatory regimes, which include different operating firms and different prices) which varied between 9% in Madrid and 35% in Asturias, as mentioned above. Therefore, quality, as proxied by rejection data, is much more homogenous within our region of interest than across regions.

Finally, as a third piece of evidence, we create for the two years for which we have rejection data (2003 and 2004) a quality-adjusted output series[18], with units with more rejections keeping an output figure closer to the original one, and units with fewer rejections yielding an output figure lower than the original one. To be precise, we multiply each output by an index that is equal to the percentage of rejected inspections by station divided by the maximum number of rejections in a year (thus, the unit with the highest number of rejections gets its output multiplied by 1). With this quality-adjusted output data we performed the DEA for 2003 and 2004[19] and obtained the VRS efficiency scores, which have a correlation coefficient of 0.81 in 2003 and of 0.83 in 2004 relative to those obtained for the same years without adjusting for quality. The average inefficiency (distance to the frontier), calculated with the quality-adjusted output is 21.12% in 2003 and 23.37% in 2004..We conclude that there is not much difference when we explicitly take this measure of quality into account. We also computed the quality-adjusted CRS efficiency scores and, in this case, the correlation is even higher: 0.91 and 0.90. Therefore, the scale efficiency measures, which involve both CRS and VRS scores, would not change much either.

(18) See Coelli *et al*. (2005).

(19) The detailed results of this quality-adjusted exercise are available upon request.

3. The determinants of efficiency scores

In this section, we perform a second-stage regression using, as the endogenous variable, a transformation of the VRS efficiency scores (θ) computed in the previous section. To be precise, we use the following logit transformation: $\ln(\theta/1-\theta)$. With this transformation, we avoid the censoring problem of the efficiency scores and, hence, OLS techniques can be implemented.

Given that, with the above logit transformation of the dependent variable, the non iid problem of efficiency scores still remains, we have used bootstrap methods as suggested by Simar and Wilson (2007) to overcome this problem[20]. We have obtained bootstrap estimates for the parameters of the exogenous variables introduced into our models using OLS (pooled estimation). Moreover, for further robustness, we have obtained, with the bootstrap technique, the estimated impact of exogenous variables for the panel data estimation given the panel structure of our dataset.

We use the second-stage results to identify the possible influential variables (significance) and their sign (positive or negative) without weighting the importance of each external variable to correct the initial efficiency scores. 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 (because tariffs were frozen starting in 2002) 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 number of vehicles (Vehicles) registered in the territories where the vehicle inspection units operate[21]. 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 that manages them. In the first case, we use the variable DV-property, which is 0 if the station is not owned by the operating firms or the regional government but by a third party, and 1 otherwise.

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(20) Note that, with the logit transformation of the efficiency scores, we can apply the Simar and Wilson (2007) procedure to the OLS estimates and we do not have to assume a censored regression in the second stage as is commonly done in the recent literature applying these techniques.

(21) 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*". Given the high correlation between Density and Vehicles we have introduced them separately into the regressions to avoid multicollinearity problems and to prove that our results are robust to different specifications.

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 manage 85% of the stations and are subsidiaries that belong to the same diversified multinational group (which operates in a number of regulated sectors across the world), while the other 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, it 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 1 for the firms belonging to the multinational group.

Usually, studies of technical efficiency are used to test the hypothesis that privately-owned firms are more efficient than state-owned firms[22]. 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. We can therefore test hypotheses concerning scope and scale efficiency at the company 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 multinational 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[23].

The results from the second-stage bootstrap estimation are presented in Table 4 (pooled estimation) and Table 5 (panel data estimation)[24]. We find that the significant variables are the number of years opened (negative impact on efficiency) and the ownership differences of the inspection station (negative impact on efficiency).

The identity of the firm is significant only if the normal distribution is assumed in the bootstrap procedure. Under this assumption, technical efficiency appears to be higher in stations belonging to a diversified group than in stations be-

(22) See Pollitt (1996).

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

(24) We also introduced a dummy variable that takes the value of 1 for inspection units that are at a distance of less than 30Km from units in other jurisdictions (Aragon and Valencia), operated by other firms. In Aragon prices are about the same as in Catalonia and rejection levels are slightly lower. In Valencia prices are substantially higher (in 2005, €41.93 in Valencia against €30.22 in Catalonia) but rejection levels are considerably lower (14% versus 21%). It can be argued that vehicle owners near jurisdictional boundaries have more bargaining power and, hence, inspection units close to other jurisdictions will operate under more powerful incentives and be closer to the efficiency frontier. When we introduced this dummy variable, the sign and significance of the other variables did not change and the coefficient of this dummy variable was not statistically significant (results are not reported but are available upon request).

Table 4: Bootstrap pooled estimation (OLS)

Variable	Observed beta	Bias	Std. Err.	[95% Conf.	Interval]	
Year Opened	-0.1714	0.0007	0.0739	-0.3163	-0.0265	(N)
				-0.3111	-0.0276	(P)
				-0.3130	-0.0297	(BC)
				-0.3196	-0.0381	(BCa)
DV-Property	1.6071	0.0021	0.7064	0.2218	2.9925	(N)
				0.2138	3.0181	(P)
				0.2374	3.0580	(BC)
				0.2747	3.1120	(BCa)
DV-Firm	0.8822	-0.0103	0.4386	0.0221	1.7423	(N)
				-0.0969	1.6824	(P)
				-0.1168	1.6650	(BC)
				-0.2011	1.6105	(BCa)
DV-0304	-0.6700	-0.0064	0.4351	-1.5233	0.1833	(N)
				-1.5439	0.1237	(P)
				-1.5371	0.1377	(BC)
				-1.5285	0.1410	(BCa)
DV-Metropolitan area	1.1232	0.0082	0.6288	-0.1099	2.3564	(N)
				0.0258	2.4171	(P)
				0.0520	2.4477	(BC)
				0.1247	2.5422	(BCa)
Vehicles	-1.22E-06	2.73E-11	7.59E-07	-2.71E-06	2.69E-07	(N)
				-2.71E-06	2.14E-07	(P)
				-2.72E-06	2.13E-07	(BC)
				-2.75E-06	1.93E-07	(BCa)
GDP per capita	-0.7487	2.1577	10.2278	-20.8070	19.3096	(N)
				-13.1687	24.9243	(P)
				-14.8879	18.2346	(BC)
				-16.2206	16.0598	(BCa)
Density	0.00012	0.0000	0.0001	-0.00003	0.00027	(N)
				-0.00004	0.00026	(P)
				-0.00003	0.00027	(BC)
				-0.00002	0.00028	(BCa)

Note: DV-property is 0 if ownership 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, Vehicles and GDPpc) are calculated for the "comarca" at which the inspection station is located. Density and Vehicles have not been introduced simultaneously into the same regression given their high correlation. We report both as a robustness check. Time span: 2000-2004. Options for confidence intervals: N= normal; P= percentile; BC= bias-corrected and BCa= bias corrected and accelerated. Number of replications 2,000.

Source: Own elaboration.

Table 5: BOOTSTRAP PANEL DATA ESTIMATION

Variable	Observed beta	Bias	Std. Err.	[95% Conf.	Interval]	
Year Opened	-0.2235	-0.0165	0.0631	-0.3472	-0.0998	(N)
				-0.3664	-0.1207	(P)
				-0.3334	-0.0775	(BC)
				-0.3426	-0.0957	(BCa)
DV-Property	1.7951	0.0895	0.5408	0.7344	2.8557	(N)
				0.8208	2.9431	(P)
				0.7248	2.7883	(BC)
				0.7596	2.8398	(BCa)
DV-Firm	0.8269	-0.0277	0.4028	0.0370	1.6168	(N)
				-0.0784	1.5017	(P)
				-0.0815	1.5008	(BC)
				-0.1854	1.4510	(BCa)
DV-0304	-0.5537	0.0561	0.3411	-1.2226	0.1153	(N)
				-1.1895	0.1591	(P)
				-1.3277	-0.0006	(BC)
				-1.3254	0.0055	(BCa)
DV-Metropolitan area	1.2174	0.0322	0.6398	-0.0373	2.4721	(N)
				0.1089	2.6257	(P)
				0.1124	2.6339	(BC)
				0.2228	2.7834	(BCa)
Vehicles	-1.29E-06	-2.71E-08	7.61E-07	-2.78E-06	2.01E-07	(N)
				-2.87E-06	1.14E-07	(P)
				-2.88E-06	1.09E-07	(BC)
				-2.91E-06	7.33E-08	(BCa)
GDP per capita	-17.9595	5.2977	17.7835	-52.8356	16.9167	(N)
				-52.1347	10.4054	(P)
				-67.3225	3.1487	(BC)
				-76.6207	1.4655	(BCa)
Density	1.10E-04	-3.98E-06	6.80E-05	-2.36E-05	2.43E-04	(N)
				-2.52E-05	2.39E-04	(P)
				-1.25E-05	2.50E-04	(BC)
				-7.03E-06	2.55E-04	(BCa)

Note: DV-property is 0 if ownership 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, Vehicles and GDPpc) are calculated for the "comarca" at which the inspection station is located. Density and Vehicles have not been introduced simultaneously into the same regression given their high correlation. We report both as a robustness check. Time span: 2000-2004. Options for confidence intervals: N= normal; P= percentile; BC= bias-corrected and BCa= bias corrected and accelerated. Number of replications 2,000.

Source: Own elaboration.

Table 6: EFFICIENCY SCORES BY TYPE OF FIRM

	Full sample VRS 2004		Multinational group VRS 2004		Small firm VRS 2004
B1	81.9	B1	81.9		
B2	80.4	B2	80.4		
B3	72.6			B3	89.8
B4	77.6	B4	77.6		
B5	81.3	B5	81.3		
B6	71.3	B6	71.3		
B7	96.8	B7	96.8		
B8	66.2	B8	66.2		
B9	69.4	B9	69.4		
B10	70.0	B10	70.0		
B11	60.6	B11	60.6		
B12	62.4	B12	62.4		
B13	80.2	B13	80.2		
B14	74.1	B14	74.1		
B15	75.3	B15	75.3		
B16	79.4	B16	79.4		
B17	92.6	B17	92.6		
B18	78.8	B18	78.8		
G1	51.0			G1	72.9
G2	71.9			G2	89.3
G3	54.7			G3	85.0
G4	51.2	G4	51.2		
G5	61.9			G5	80.6
G6	73.5			G6	98.1
G7	57.2			G7	87.7
L1	73.4	L1	73.4		
L2	53.4	L2	53.4		
L3	55.1	L3	55.1		
L4	72.3	L4	72.3		
L5	58.8	L5	58.8		
L6	57.7	L6	57.7		
L7	80.9	L7	80.9		
L8	100.0	L8	100.0		
T1	84.8	T1	84.8		
T2	67.5	T2	67.5		
T3	63.0	T3	63.0		

Table 6: EFFICIENCY SCORES BY TYPE OF FIRM (continuation)

	Full sample VRS 2004		Multinational group VRS 2004	Small firm VRS 2004
T4	67.4	T4	67.4	
T5	77.3	T5	77.3	
Kruskal-Wallis test (Equality of populations)				Rank Sum
Multinational firm		(obs)	31	654
Small local firm		(obs)	7	87
Chi-squared (1 d.f.)			3.474	
Probability			[0.0623]*	

Note: All scores obtained using sequential frontiers and an input-oriented DEA. Null hypothesis of the Kruskal-Wallis test is that both sub-samples belong to the same population.

Source: Own elaboration.

longing to a firm which is not diversified but specializes in vehicle inspection and manages around 15% of the inspection units in Catalonia. These results would be 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.

Finally, note that, in the panel data case, the bootstrap estimates give a significant and positive impact for the variable that accounts for the station located in the metropolitan area of Barcelona. The location characteristics (Density, GDPpc and Vehicles) are not significant in any of the regressions performed.

To further analyze the difference in efficiency between the multinational group and the small firm, we divided the sample into two sub-samples: one belonging to the multinational group and the other to the small local firm. We constructed sub-frontiers corresponding to the sub-samples and computed efficiency scores for each sub-sample. We find that vehicle inspection units of the multinational group keep the same scores (because they were actually the ones defining the initial efficiency frontier) while the sub-sample for the small (non-multinational) firm obtains lower efficiency scores. Using a Kruskal-Wallis test, we analyze whether the scores of the two sub-samples belong to the same sample. The results of the test show that they do not belong to the same sample at the 10% level of significance.

Both pieces of evidence (the bootstrap results and the Kruskal-Wallis test) on the impact of ownership on efficiency lead us to conclude that there is some weak evidence that the units belonging to the multinational group are more efficient. We also conjecture that this efficiency differential could be further exploited by the regulator by applying more powerful incentives (through price-caps, yardstick competition or liberalization, or some combination of them).

Table 7: SUMMARY RESULTS FOR RAY AND DESLI (1997) MALMQUIST INDEX DECOMPOSITION

Index	TC	TEC	SC	RD
2000-2001	1.0662	0.8923	0.9454	0.9432
2001-2002	0.9945	1.0115	1.0197	1.0245
2002-2003	0.9140	1.0996	1.1188	1.0308
2003-2004	1.0117	0.9810	0.9940	0.9978
Mean	0.9966	0.9961	1.0195	0.9991
Percentage change	**TC**	**TEC**	**SC**	**RD**
2000-2001	6.62%	-10.76%	0.37%	-5.68%
2001-2002	-0.55%	1.15%	1.85%	2.45%
2002-2003	-8.60%	9.96%	3.07%	3.08%
2003-2004	1.17%	-1.90%	0.55%	-0.22%
Mean	-0.34%	-0.39%	1.46%	-0.09%

Note: TC: technical change. TEC: technical efficiency change. SC: scale efficiency change. Individual scores calculated using sequential frontiers.

Source: Own elaboration.

4. THE EVOLUTION OF EFFICIENCY AND REGULATORY UNCERTAINTY: MALMQUIST INDICES

The RD Malmquist index decomposition described in Section 2 is presented in Table 7. 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).

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 first and the second year (2000-2001), when tariffs were routinely increased at the proposal of the 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 determinants of this evolution, but we conjecture that it may have to do with the regulatory uncertainty in 2003 and 2004, which we will describe below.

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 prior to elections for 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 about 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 static incentives (technical efficiency and scale efficiency) as much, since firms had to work harder to make a profit, given that the government was refusing to increase tariffs.

5. Conclusions and policy implications

The results of this study of vehicle inspection units with homogenous quality 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 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 weakly show better productive efficiency, reflecting the fact that economies of scale or scope at the firm level may, to some extent, be captured by the current regulatory system. 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)[25]

(25) With liberalization or incentive regulation, quality (so far high) becomes a concern. However, with multinationals, international and inter-temporal reputation may exert some control on incentives to lower quality.

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 2003 and 2004 may be the reason for the absence of technical progress in those years in our sample of inspection units.

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 multinational firms, which may already be providing some results in terms of higher technical efficiency. Incentive regulation would probably be accompanied by an 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[26].

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. The sample corresponds to one single region in a short period of time and the inputs are measured in a broad way. Frontier methods, such as DEA, reveal relative efficiencies. It may well be that, when compared with similar units in other jurisdictions, the results will differ. Future research should perform comparisons of this kind and then differences in regulatory systems could be introduced into our second stage regressions to draw lessons about the costs and benefits of different rules of the game. Nevertheless, our study illustrates the potential for using productive efficiency analysis to guide regulatory reform.

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

(26) One of these other diversified multinational firms sued the Catalan government in 2003 for the extension of the concession period (see Section 3). This reveals another potential benefit of competition, which, to our knowledge, remains unexplored in the literature: when there are multinationals operating in some jurisdictions but not in others, competition for the rules puts pressure on potentially captured local regulators.

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	2.4	2.3	2.3	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	1.9	2.0	2.0	2.0	1.9
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	1.0	1.0	1.3	1.3
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	1.6	1.2	1.2	1.5	1.5
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	1.9	1.8	1.8	1.9	1.8
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	80.4	76.2	84.0	79.8	100.0	82.2	78.2	85.3	81.9	100.0	97.8	97.4	98.5	97.4
B2	100.0	98.0	92.0	64.5	74.3	100.0	98.4	92.1	68.8	80.4	100.0	99.6	99.9	93.8	92.4
B3	61.3	67.5	71.5	76.1	65.9	73.7	77.9	81.0	84.6	72.6	83.2	86.6	88.3	90.0	90.8
B4	92.1	80.3	67.2	74.4	74.2	97.9	80.7	69.5	77.6	77.6	94.1	99.5	96.7	95.9	95.6
B5	54.5	52.9	55.0	68.9	72.4	68.2	64.0	65.6	78.5	81.3	79.9	82.7	83.8	87.8	89.1
B6	94.2	86.8	82.0	69.3	70.3	100.0	86.9	82.5	70.4	71.3	94.2	99.9	99.4	98.4	98.6
B7	62.4	57.2	63.5	92.8	96.7	68.7	64.0	69.8	93.0	96.8	90.8	89.4	91.0	99.8	99.9
B8	51.4	44.3	46.0	52.9	54.8	65.5	55.1	56.9	64.7	66.2	78.5	80.4	80.8	81.8	82.8
B9	85.5	98.2	97.6	70.2	61.5	93.8	100.0	99.6	76.2	69.4	91.2	98.2	98.0	92.1	88.6
B10	73.7	59.2	56.3	70.3	68.2	86.8	66.2	63.1	71.5	70.0	84.9	89.4	89.2	98.3	97.4
B11	52.5	46.0	45.0	47.4	48.3	67.3	58.3	57.2	59.8	60.6	78.0	78.9	78.7	79.3	79.7
B12	37.2	31.0	31.9	39.5	40.3	89.9	57.9	58.9	61.8	62.4	41.4	53.5	54.2	63.9	64.6
B13	69.3	66.1	71.6	67.5	77.1	82.6	74.1	78.4	75.7	80.2	83.9	89.2	91.3	89.2	96.1
B14	76.9	60.5	97.4	67.8	70.6	87.6	63.9	98.7	71.7	74.1	87.8	94.7	98.7	94.6	95.3
B15	100.0	98.2	84.4	88.4	74.1	100.0	99.0	84.5	88.4	75.3	100.0	99.2	99.9	100.0	98.4
B16	48.7	43.5	45.7	63.3	71.4	63.2	55.6	57.9	74.1	79.4	77.1	78.2	78.9	85.4	89.9
B17	99.6	95.0	99.5	94.4	92.4	100.0	95.4	99.7	94.5	92.6	99.6	99.6	99.8	99.9	99.8
B18	44.2	43.1	44.0	65.0	68.6	63.7	56.1	57.0	76.5	78.8	69.4	76.8	77.2	85.0	87.1

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}).

Source: Own elaboration.

Table A2: EFFICIENCY SCORES BY UNIT (continuation)

	CRS efficiency scores					VRS efficiency scores					Scale efficiency scores				
	2000	2001	2002	2003	2004	2000	2001	2002	2003	2004	2000	2001	2002	2003	2004
G1	68.2	62.4	63.2	56.8	41.5	74.1	66.9	67.6	61.7	51.0	92.0	93.3	93.5	92.1	81.4
G2	59.9	51.3	54.8	66.0	61.1	73.8	61.8	64.5	75.8	71.9	81.2	83.0	85.0	87.1	85.0
G3	47.2	41.4	41.9	43.3	41.0	100.0	55.3	55.7	56.9	54.7	47.2	74.9	75.2	76.1	75.0
G4	19.6	20.7	21.7	19.7	20.1	64.3	57.1	58.2	51.0	51.2	30.5	36.3	37.3	38.6	39.3
G5	58.1	55.2	57.2	56.1	50.1	72.8	68.1	69.7	67.1	61.9	79.8	81.1	82.1	83.6	80.9
G6	63.8	59.9	63.8	68.8	67.9	76.0	66.9	70.0	74.0	73.5	83.9	89.5	91.1	93.0	92.4
G7	32.2	30.1	32.9	32.5	30.9	80.4	57.2	60.6	59.4	57.2	40.0	52.6	54.3	54.7	54.0
L1	58.4	100.0	100.0	63.7	65.7	68.8	100.0	100.0	71.3	73.4	84.9	100.0	100.0	89.3	89.5
L2	17.5	14.7	15.2	18.2	18.6	60.5	44.9	45.3	53.2	53.4	28.9	32.7	33.6	34.2	34.8
L3	21.1	22.1	23.2	22.1	23.0	63.7	56.7	58.0	54.4	55.1	33.1	39.0	40.0	40.6	41.7
L4	42.0	33.8	34.9	40.3	41.0	99.6	61.3	62.5	71.6	72.3	42.2	55.1	55.8	56.3	56.7
L5	27.9	22.2	23.3	26.8	26.0	79.8	52.0	53.2	60.1	58.8	35.0	42.7	43.8	44.6	44.2
L6	20.4	19.0	20.3	22.6	23.1	66.0	50.9	52.4	57.3	57.7	30.9	37.3	38.7	39.4	40.0
L7	19.7	19.6	19.7	22.7	23.5	83.1	73.2	73.1	80.6	80.9	23.7	26.8	26.9	28.2	29.0
L8	16.3	17.2	17.6	19.2	20.0	100.0	100.0	100.0	100.0	100.0	16.3	17.2	17.6	19.2	20.0
T1	71.5	100.0	96.2	79.6	81.7	84.7	100.0	97.5	83.4	84.8	84.4	100.0	98.7	95.4	96.3
T2	55.7	48.9	50.8	52.9	55.7	70.5	61.1	63.1	65.3	67.5	79.0	80.0	80.5	81.0	82.5
T3	32.0	31.1	32.0	32.3	34.2	80.7	60.6	61.5	60.8	63.0	39.7	51.3	52.0	53.1	54.3
T4	35.9	31.6	33.0	37.1	38.5	87.5	57.5	59.2	65.8	67.4	41.0	55.0	55.7	56.4	57.1
T5	56.6	75.5	85.6	69.0	69.8	69.2	79.2	85.9	76.7	77.3	81.8	95.3	99.7	90.0	90.3

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}).

Source: Own elaboration.

Table A3: CORRELATION COEFFICIENTS OF SCORES OBTAINED WITH SEQUENTIAL AND CONTEMPORANEOUS FRONTIERS

	2000	2001	2002	2003	2004
VRS	1.000	0.983	0.975	0.924	0.945
CRS	1.000	0.955	0.995	0.965	0.979

Source: Own elaboration.

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RESUMEN

El cálculo de la eficiencia productiva proporciona información sobre los efectos potenciales de la reforma regulatoria. Presentamos un ejercicio a partir del análisis de la envolvente de datos (DEA) de una muestra de 38 unidades (entre los años 2000 y 2004) de inspección de vehículos bajo un régimen de concesión, con un nivel homogéneo de calidad que se supervisa por el regulador regional. Las diferencias en los índices de eficiencia muestran la ganancia potencial de la eficiencia técnica al introducir alguna forma de regulación por incentivos o de avanzar hacia la liberalización. También calculamos los índices de eficiencia de escala, mostrando que sólo aquellas unidades en los territorios menos densamente poblados operan con tamaños sub-óptimos. Entre las que funcionan a una escala óptima, hay diferencias significativas de tamaño; las más grandes operan en territorios con la densidad demográfica más elevada. Estos resultados sugieren que la introducción de nuevas unidades en los territorios más densamente poblados (un efecto esperado de la liberalización) no tendría efectos negativos en términos de eficiencia de escala. La identidad de la empresa propietaria de la estación de inspección parece determinar la distancia a la frontera eficiente. Finalmente, mostramos que entre 2002 y 2004, un periodo de elevada incertidumbre en la región de la muestra, el cambio técnico fue prácticamente nulo. La reforma regulatoria debe tomar en cuenta los efectos de diversificación y escala, al tiempo que evitar la incertidumbre regulatoria.

Palabras clave: Eficiencia productiva, reforma regulatoria, inspecciones de vehículos.

Clasificación JEL: C61, L51, R38.