ON THE EFFICIENCY OF TOLL MOTORWAY COMPANIES IN SPAIN

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Abstract

This paper uses stochastic frontier analyses to estimate the cost efficiency of toll motorway companies in Spain, disentangling between two types of efficiency: persistent efficiency, related to project building and sunk costs, and transient efficiency, more closely related to management efficiency. The differences between the two sources of efficiency are significant, allowing us to test how different regulations impact performance. We find that regional governments grant more efficient projects than those granted by central government, but we do not find significant differences in performance in relation to the public/private ownership share, following the privatization of publicly owned concessionaires or due to changes in price updating regulations (price cap). The motorways nationalized in the 1980s had lower persistent efficiency levels, while management seems to have had a limited role in promoting efficiency gains. Furthermore, our results support the existence of scale and density economies in Spain, showing that an increase in vehicle-kilometers is more important than extending the motorway.

Keywords: Motorways; Efficiency; Stochastic Frontier, Concessions, Infrastructure.

JEL Codes: D24; D78; H54; L32; L33; L90.

1. INTRODUCTION

Road transport, as a major means of transportation, has had a significant influence on all areas of economic, political and social development since earliest times. Indeed, its role in public infrastructure investment and its links with economic growth, productivity and employment have been extensively studied, most notably in the economics literature since Aschauer's seminal work (1989).[1] Yet, very little is known about the efficiency and productivity of motorway management and the impact produced by specific public policies and reforms related to motorway ownership and regulation.

In some countries, motorway networks are managed directly by the State (or by a publicly owned corporation operating under private law), while in others, private companies manage motorways under concession contracts, a toll being charged as a return on their investment and to meet maintenance and operation costs. These Public-Private Partnership (PPP) contracts are designed and awarded in the expectation of improving efficiency and, above all, of facilitating private financing. However, toll regulation has typically been shown to be unrelated to the degree of productivity or the efficiency of concessionaires (Albalate, Bel and Fageda, 2009), especially in the absence of price-cap regulation (Iossa, 2015), and satisfying uncertain demand in the long run is the main factor determining the outcome of the standard fixed-term concession contract (Engel, Fischer and Galetovic, 1997a; 2001).[2] Even if motorway managers appear to

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[1] See Matas, Raymond and Roig (2015) for recent studies on the link between road investments and productivity; See Jiwattanakulpaisarn et al. (2009) and Albalate and Fageda (2015) for recent studies on the link between motorways and employment.

[2] Determinants of motorway demand that lie beyond the control of the concessionaire include fuel prices, macroeconomic conditions, population growth, per capita income distribution, the existence of alternative cheaper roads or modes of transportation, changes in urbanization and land use, weather conditions and changes in transport technology (Yescombe, 2007; Albalate, 2014; Iossa, 2015)

have little scope for improving their overall cost efficiency, given the overriding importance of capital costs (investment) in their cost structure, and "can do little to increase demand", as Engel, Fischer and Galetovic (2002, p. 22) claim, the empirical literature remains scarce and overly limited to allow us to draw any general conclusions about efficient management in the sector and its determinants.

Clearly, regulators seek to increase the efficiency of service providers by implementing regulatory and policy changes. To this end, analyses of the efficiency of regulated industries, such as energy systems (Lin and Wang, 2014; Chen, Pestana and Borges, 2015; Ghosh and Kathuria, 2016) and water services (Phillips, 2013; Carvalho and Cunha-Marques, 2016); transport services, including buses (Bel and Rosell, 2016, Vigren, 2016; Wegelin, 2018) and railroads (Couto and Graham, 2009); and transport infrastructures such as ports (Cullinane et al., 2006; Tongzon and Heng, 2005) and airports (Martin and Voltes-Dorta, 2011; Adler and Liebert, 2014), have figured among the most frequent applications of cost efficiency analysis using (stochastic) frontier models. Recently, such efficiency analyses have begun to distinguish between transient and persistent inefficiency, where the latter absorbs structural problems in the firm or systematic shortfalls in its management, and the former is a time-variant component that absorbs changes in a firm's efficiency. However, the empirical literature in general has failed to pay sufficient attention to the distinction between these two components of a firm's efficiency (Filippini and Greene, 2016). A number of recent analyses, focusing on energy efficiency (Filippini and Hunt, 2015), banking (Mamatzakis et al., 2015) and the nursing home sector (Di Giorgio et al., 2015), nevertheless, emphasize the importance of distinguishing between these two types of efficiency and of measuring it accurately for policy analysis. Since most of the regulators use carrot-and-stick principles, they have to quantify the margin by which they have to increase their efficiency. Moreover, the literature dedicated to studying the efficiency of public utilities has largely neglected the motorway industry with just a few specific exceptions, most notably Benfratello, Iozzi and Valbonessi (2009) for Italy, and Odeck (2008a) and Welde and Odeck (2011) for Norway.

This paper extends this literature by drawing on a new, self-constructed dataset for Spain, the country with the largest number of private concessionaires (for-profit) and with a longstanding tradition of PPPs (Albalate, 2014). The Spanish experience is particularly insightful due to the lessons it can offer. Spanish motorway concessionaires have experienced periods of vigorous economic growth and financial distress, have had to adapt to a variety of regulatory reforms, and have undergone transitions from private to public management via the nationalization of bankrupt concessionaires and the privatization of publicly owned toll motorway companies. This variety of experience makes Spain an interesting case in which to evaluate how policy changes and reforms affect efficiency.

The dataset covers a time span of 26 years, from 1988 to 2015, and allows us to evaluate the efficiency of concessionaires during these distinct periods. Moreover, it means we can take into consideration regulatory changes (price cap schemes, privatizations, etc.) and the different features of motorways (length, network expansions, physical features, technological advances, etc.) that might have impacted on concessionaire cost efficiency. We analyze the effects of a variety of public policies and regulatory reforms on the efficiency of toll motorway companies by specifically reporting transient and persistent efficiency estimations. Furthermore, we contribute to the literature by undertaking a stochastic frontier analysis (SFA) to estimate cost efficiency in the motorway sector distinguishing between time variant and invariant efficiency.

The remainder of this paper is organized as follows. Section 2 describes the extant literature examining the efficiency of motorways. In section 3, we outline our technical approach by presenting the model implemented. Section 4 presents our data and the main descriptive statistics on Spanish motorways. Our results are presented and discussed in section 5. Finally, section 6 provides our main conclusions and policy recommendations.

2. LITERATURE REVIEW

The literature analyzing the efficiency of motorway management is scant. To the best of our knowledge, only two experiences of toll road concessions have been examined in the literature: the Norwegian and Italian cases. In the former, efficiency was first estimated by Amdal et al. (2007) and Odeck (2008a). Since concessionaires are public companies under local authority ownership, the Norwegian case is unusual. As Estache and de Rus (2000) highlighted, the system uses dedicated non-profit companies to collect tolls, while the government road administration retains responsibility over road design, construction and maintenance (see Odeck, 2008a). These characteristics make Norway quite a singular case, with few points in common with the Spanish case.

Amdal et al. (2007) used panel data for 26 toll collection companies – including some toll cordons – with a time series that extends between two and seven years (1998 to 2004). They found evidence of sizable unexploited economies of scale in costs when estimating a translog cost function for traffic and other controls with a random effects estimator. Average costs were reported to be decreasing in traffic volume for low levels, becoming flat for high-density traffic. Other controls, such as the number of lanes and total debt were both positively correlated with operating costs. However, the former appeared to be especially sensitive – probably due to their correlation with traffic – to model specification, becoming insignificant in the simplest models. In contrast, competitive tendering and the number of cars with on board paying units lowered operating costs, which points to the relevance of regulation and technology advances in toll collecting systems.

Odeck (2008a) also evaluated this experience but employed a different methodological approach, namely, a non-parametric data envelopment analysis (DEA) to assess input technical inefficiency. The sample comprised 18 companies over a time span of four years (2001-2004). Results also confirmed the potential for efficiency gains (of about 14 per cent) and the existence of economies of scale. New electronic methods of collecting tolls seemed to contribute to efficiency improvements, but represented sizable investments in the short run. Another result worth mentioning was the role of company age, found to be positively associated with efficiency, which could point to some sort of learning effect.

Later, Welde and Odeck (2011) expanded their DEA to include an SFA for a production function. This study examined a six-year period (2003-2008) and considered 20 toll companies. The main finding once again was the significant potential for efficiency improvements and further evidence of the importance of technology advances in toll collection. The age of the toll company, however, appeared to be sensitive to the method used, given that it was significant according to SFA, but not according to DEA, which contradicted previous evidence. However, the authors reported the absence of economies of scale (also contradicting earlier evidence presented in Odeck, 2008a), a result that was maintained irrespective of the method applied. The paper's findings also contradicted the results of Amdal et al. (2007) as regards the contribution of competitive tendering, although the efficiency considered in the latter study by was based on average costs rather than on a production function.

The second experience evaluated by the literature is that of the Italian motorway sector. A number of early studies on productivity and operating efficiency were somewhat limited from a technical perspective and focused on the impact of privatization. Ragazzi (2008) found evidence of economies of scale, although the study links this result to the importance of *Autostrade* (the country's leading privatized concessionaire in what is a small sample), and the fact that its operation costs were much lower than the industry mean. Massiani and Ragazzi

(2008) provided findings on the relationship between privatization and efficiency. They reported no statistically significant impact of the privatization of the network on productivity. The authors considered productivity ratios based on traffic with respect to costs, and traffic revenues with respect to total costs, as being invalid. Rather, they claimed that productivity should be assessed by means of the sole consideration of operating costs, since amortization and financial costs depend upon historical investment costs and the length of the concession. Here, they found that operating costs largely depended on traffic and capacity, but they found no clear evidence of economies of scale.

A more technical, in-depth analysis of the Italian toll motorway sector was performed by Benfratello, Iozzi and Valbonesi (2009). This was the first paper to study a stochastic cost frontier function for the motorway sector. Their sample included 20 Italian concessionaires and covered a time span of 13 years (1992-2004). Italy's experience is much more similar to that of Spain's, with a large presence of private companies, which makes this paper the closest to ours. Their empirical analysis based on SFA for a cost function concluded that the industry clearly exhibited scale economies for small- and medium-sized concessionaires operating in the Italian network. An equiproportional increase in traffic and network size caused a less than proportional increase in costs for networks up to 300 km. Besides scale economies, the authors also found large density economies and steady productivity gains over time. Interestingly, the authors found that privately owned concessionaires have a cost advantage of about 3% over their publicly owned counterparts. By contrast, the introduction of a price cap – which in theory should serve as a productivity-enhancing mechanism – did not have any effect on efficiency. Unfortunately, given the nature of their dataset, they could not establish the size of the network at which the economies of scale become exhausted.

3. METHODOLOGY: COST FUNCTION AND ECONOMETRIC MODELS

The estimation of frontier functions is the econometric exercise of making the empirical implementation consistent with the underlying theoretical proposition that no observed agent can exceed the ideal (Greene, 2008). In practice, the frontier function model is a regression model that allows efficiency to be measured, that is, an empirical estimation of the extent to which firms achieve a theoretical ideal. Only a few firms typically manage to operate at this frontier. Measuring the resulting efficiency is the ultimate goal of stochastic frontier analysis.

Parametric approaches can be subdivided into deterministic and stochastic models. Deterministic models allow the researcher to distinguish between technical efficiency and statistical noise, while the stochastic approach takes into consideration both technical efficiency and random noise. On a stochastic frontier, one company can usually be assumed to operate at the efficiency level. Farrell (1957) was the first to measure productive efficiency empirically. This efficiency is evaluated by comparing best firm practice with that of the rest.

We adopt a stochastic cost frontier model for panel data in order to analyze the impact of different variables on a concessionaire's total costs. The cost function gives the minimum expenditure needed to produce a given output. The purpose of a motorway concessionaire is to maximize the total distance covered by the vehicles, assuming total costs to be a function of input prices. Capital costs are included since the concessionaire expands the investment over time, not only when the highway is built. About a third of the total initial investment is extended (additional lanes in some parts, technology in the toll system, etc.), so it is our contention that this must be taken into account in the objective of cost minimization. Aigner et al. (1977) and Meeusen and Van den Broeck (1977) propose the first estimation procedure for inefficiencies, an important derivative when estimating the frontier cost function. Based on previous studies, a cost function can be specified:

(1)

$$\mathrm{TC}_{it} = f(Y_{it}, PL_{it}, PM_{it}, PC_{it}, N_{it}, T)$$

where the total cost of concessionaire firm TC is assumed to be a function of output Y, factor prices PL (price of labor), PM (price of maintenance) and PC (price of capital), network characteristics N and a time trend T. In this sector, just what constitutes the network characteristics that account for differences between motorway concessionaries is open to debate. Motorway length is one characteristic that has an impact on total costs. The number of accidents with victims is potentially another relevant motorway characteristic, given that a concessionaire seeks to minimize such accidents because of their associated costs and because of the negative effect they have on user perceptions regarding safety.[3]

Our main objective is to estimate a translog cost function. The translog has the advantage that it does not impose *a priori* restrictions on the nature of the technology. However, should the model specification include variables that are relatively highly correlated, then the estimation of the translog cost function can suffer from multicollinearity. Therefore, we estimate a reduced version of the translog, where all interaction variables between the price of inputs, the output and network characteristics have been dropped.

As a result, the stochastic cost frontier equation to be estimated can be expressed in the following double log form:

(2)

[3] The total number of accidents could be a substitute for accidents with victims, but there is a discontinuity in the way the total number of accidents has been defined since 2004 by some concessionaires.

$$\ln\frac{TC_{it}}{PC_{it}} = \beta_0 + \beta_{PL}\ln\frac{PL_{it}}{PC_{it}} + \beta_{PM}\ln\frac{PM_{it}}{PC_{it}} + \beta_Y \ln Y_{it} + \beta_{LEN}\ln LEN_{it} + \beta_{ACC}\ln ACC_{it}$$

$$+ \frac{1}{2}\beta_{PLPL}\ln\left(\frac{PL_{it}}{PC_{it}}\right)^2 + \frac{1}{2}\beta_{PMPM}\ln\left(\frac{PM_{it}}{PC_{it}}\right)^2 + \frac{1}{2}\beta_{YY}(\ln Y_{it})^2$$

$$+ \frac{1}{2}\beta_{LENLEN}(\ln LEN_{it})^2 + \frac{1}{2}\beta_{ACCACC}(\ln ACC_{it})^2 + \beta_T T_t + u_{it} + \upsilon_{it}$$

where $i = 1, 2, \dots, 31$ denoting the concessionaire and $t = 1988, 1989, \dots, 2015$ denoting the year. The total costs (TC) are the sum of labor, maintenance and capital costs, where the price of labor (PL), the price of maintenance (PM) and the price of capital (PC) are the three input factor prices. The output (Y) is the number of vehicle-kilometers. The network characteristics are the motorway length (LEN) and the number of accidents with victims (ACC). Finally, *T* is a time trend that captures changes in the cost over time. The random term is divided into a normally distributed error term υ_{it} and the non-negative inefficiency term u_{it} following a truncated non-negative normal distribution $N^+(0, \sigma_v^2)$. Between both terms, there is an independent distribution assumption. Estimating a cost frontier allows us to compare the performance on two sides of the model: that of the cost function coefficients and that of efficiency. There is some evidence of a trade-off between the coefficients estimated and efficiency.

The cost inefficiency measures how much a motorway concessionaire is able to reduce its costs while maintaining the same level of output. In a context in which demand is determined and cannot be stored, as is the case of the motorway sector, this is especially relevant. We use input-oriented efficiency measurement, that is, a concessionaire's objective is to produce a given level of output at the minimum possible cost. This view is useful if the output, for example, vehicle-kilometers, is exogenously given.[4] After all, on the cost side, any errors in optimization, technical or allocative, must show up as higher costs.

The first application of panel data models to SFA was undertaken by Pitt and Lee (1981) in the form of a random effect model (RE). The authors assume that the inefficiency term u_i is constant in time and that it captures firm inefficiency; concessionaire specific inefficiency is the same in each time period. This might represent quite a strong assumption for a long panel, although it might be plausible when a firm operates in a non-competitive environment, such as that of motorway concessions. In a regulated industry, all firms might be operating under excess capacity, which could be reflected in high inefficiency values. Another limitation of this model is that no correlation is assumed between the explanatory variables and inefficiency. In these models, any individual-specific or unobserved heterogeneity is captured by the inefficiency term u_i or a constant: the Pitt and Lee model (1981) underestimates the level of efficiency.

A shortcoming in the Pitt and Lee (1981) model is that it cannot disentangle a firm's inefficiency from cost differences due to the unobserved characteristics of the concession area. Usually, such companies cannot control for those concession characteristics such as the terrain slope, viaducts or tunnels needed, etc. that cannot simply be attributed to concessionaire performance. To overcome this problem, Greene (2005a and 2005b) proposes a model that captures invariant unmeasured unobserved heterogeneity in a specific term, besides a firm-specific inefficiency term and a random noise term. The true random effects (TRE)

[4] Although toll motorway companies wish to increase the outcome variable to collect more revenues, there is sufficient consensus in the literature to believe that traffic can be considered exogenous. The action of the concessionaire exerts some impact on demand, but the sensitivity of their returns to the materialization of demand is not proportionate to the limited degree of control that it has over this variable (Tirole, 1997). Indeed, traffic risk depends little on what the concessionaire does, nor is it possible to estimate this risk with any acceptable degree of precision (Engel et al., 1997b). This is because demand is basically affected by elements outside the control of the concessionaire, such as population growth, distribution and movement; economic activity and location; land use; travel patterns; choice between modes and between public and private transportation.

specification, unobserved cost differences across firms that remain constant over time, is driven by unobserved characteristics rather than by inefficiency. Thus, time invariant inefficiency is interpreted as concessionaire specific heterogeneity, as it is not captured by the inefficiency term. This time invariant unobserved characteristic not absorbed by the inefficiency term is beyond the control of the concessionaire due to the concession characteristics.

Recently, models have focused on separating productive efficiency into its persistent and transient parts within the same model. The first studies in this line were Colombi et al. (2014), Tsionas and Kumbhakar (2014), Kumbhakar, Lien and Hardaker (2014) and Filippini and Greene (2016). Kumbhakar, Lien and Hardaker (2014) proposed a model that splits the error term in four components in order to capture these effects, estimating the firm's inefficiency using the conditional mean of the efficiency term proposed by Jondrow et al. (1982).

The persistent term is related to the presence of structural problems in the organization of the production process of a concessionaire or to the presence of systematic shortfalls in managerial capabilities. This cost efficiency does not vary over time, and can be caused by structural problems in the motorway concession, by structural factors that have not been well allocated, by geographic heterogeneity or by long-term management mistakes, among others. The Pitt and Lee (1981) model tends to reflect the persistent part of the time-invariant values.[5] In contrast, the transient term is related to the presence of non-systematic management problems that can be solved in the short term, improving the efficiency levels. This part is time varying,

[5] Battese and Coelli (1995) introduce time variation and environmental variables. However, the time invariant random component is still a major influence on the component. Results differ greatly from those provided by models in which the random part varies with time. That is, a concessionaire observed in two periods is treated as two different firms. This assumption does not allow us to estimate the inefficiency level consistently since its variance does not vanish as the sample size increases

reflecting temporal management mistakes or temporal events affecting the concession. Whereas a transient efficiency due to short-run rigidities or mismanagement is easy to increase, input allocation is difficult to change in order to increase the concessionaire's persistent efficiency.

In Greene's TRE model, any persistent component of the inefficiency is absorbed in the individual-specific constant term and, not accounted for in its efficiency. In industries in which certain sources of efficiency result in time-invariant excess of inputs, the estimated inefficiency could be relatively small. Filippini and Greene (2015) find that the TRE model tends to estimate the transient part of efficiency, whereas the Pitt and Lee (1981) model does not capture persistent efficiency well. The efficiency index is calculated using the estimator of Battese and Coelli (1988) in TRE and Pitt and Lee model.

Note at this point that the main reason for focusing on stochastic frontier analysis rather than on other methods, such as data envelopment analysis (DEA), is to separate both types of efficiency. However, recent applications on DEA have begun to address this separation of efficiency types (Pérez-López et al., 2018). Although in this paper we do not compare the two methodologies, it is something that should be taken into account in future studies.

A derivative from the half translog approach is the possibility it affords of calculating the economies of density and scale. The economies of density (ED) are defined as the inverse of the elasticity of costs with respect to output; the relative increase in total costs resulting from an increase in vehicle-kilometers, holding input prices and the network characteristics fixed:

$$ED = \left(\frac{\partial lnTC}{\partial lnY}\right)^{-1} = (\beta_Y + \beta_{YY} lnY)^{-1} \qquad (3)$$

Economies of density imply that the average total costs of a motorway concessionaire fall as vehicle-kilometers increase. These economies exist if ED is greater than one;

diseconomies of density are present for values less than one; while values equal to one indicate that the firm is operating at the optimal level, holding all other factors constant.

Economies of scale (ES) measure the reaction recorded by total costs when the output and the network length increase in the same proportion, holding other network characteristics and input prices fixed:

$$ES = \left(\frac{\partial lnTC}{\partial lnY} + \frac{\partial lnTC}{\partial lnLEN}\right)^{-1} = (\beta_{Y} + +\beta_{YY} lnY + \beta_{LEN} + \beta_{LENLEN} lnLEN)^{-1} \quad (4)$$

Thus, economies of scale exist if ES is greater than one, that is, the average total costs of a motorway concessionaire decrease as the vehicle-kilometers and motorway length increase in the same proportion, holding all other parameters constant. Economies of scale exist if ES is equal to one and diseconomies of scale exist if ES is less than one. It is important to assume that any increase in the network length raises the output level in the same proportion (Caves et al., 1984).

4. DATA

The Spanish motorway industry forms part of the country's national road network, providing public service infrastructure. The dataset used in this paper is extracted from the annual reports published by the Secretary-General of Infrastructure and Transport at the Spanish Ministry of Transportation. The first year included is 1988, given that in years prior to that date the majority of variables are unavailable. The result is an unbalanced data panel, where the total number of observations through to 2015 is 461. In the initial years, between eight and ten companies are compared, while by the end of the period the number of concessionaires reaches thirty-one. The dataset includes all of Spain's tolled motorways, with the exception of some of the Basque country's motorways for certain years. The Basque *foral* regime (specific fiscal arrangements) means that public firms are under no obligation to report data to the central government. The sample, however, does represent 96 per cent of the total motorway observations.

The information available for any given year includes total costs, structural costs, capital costs, vehicle-kilometers, number of employees, motorway lengths and number of accidents. The cost function includes one output, three inputs, two network variables and a time trend.

On the cost function side, the total cost (TC) is the dependent variable and includes labor, maintenance and capital costs.[6] The price of labor (PL) is given by the ratio between total salaries and the total number of full-time equivalent workers.[7] The price of maintenance (PM) is calculated as material and external service costs divided by the motorway length. The price of labor and maintenance should be positive. The price of capital (PC) is obtained by amortizing the costs of all concessionaire investments related to motorway length and the financial costs. This variable divides the other price inputs and the total costs.

On the output side, the literature considers two main groups: supply- and demand-related measures. Supply measures, such as network length multiplied by the number of lanes, are the most suitable. However, the relative homogeneity of motorways and the absence of available data mean this is not an option available to us. On the demand side, the number of vehicles is a key determinant. However, several concessionaires have more than one motorway, or there are marked differences on the same motorway in terms of average daily traffic, depending on the measurement point. For this reason, the output (Y) variable opted for is vehicle-kilometers,

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[6] All costs are adjusted for inflation using the Spanish CPI, measured in 2002 euros. Before 2001, financial data have been converted from the former Spanish currency (pesetas) to euros.

[7] Input prices are calculated as in other sectors, and in line with Benfratello et al. (2009) for the motorway sector.

which accounts for the distance travelled by every vehicle.[8] It should be noted that this demand indicator reflects consumer preferences, above and beyond the objectives of the concessionaire under control. The necessary assumption of output being exogenous is based on the monopolistic structure of the motorway concessions. The expected sign is positive, that is, an increase in the number of vehicles and in the distance travelled should result in higher total costs for the concessionaire. However, we question whether the addition of more vehicles would result in a stronger relation with total costs.

As for the network characteristics, total motorway length (LEN) captures the network size. We expect a positive relation between motorway length and total costs. One variable of network quality is the number of accidents suffered by the concession (ACC). The concessionaire has incentives to minimize the number of road accidents since they result in emergency costs, traffic jams and a lower user-perceived quality. We expect a positive sign; that is, total costs should increase if the number of accidents increases.

The time trend should capture technological progress. Here, we would expect a negative sign because, although this sector is not characterized by significant changes in production technology, after several years a certain technological progress can be expected.

Table 1 reports summary statistics for the concessionaires. Information for total costs, price of inputs, inputs, vehicle-kilometers, network length, and the number of road accident victims includes the mean, standard deviation, and first and third quartiles. Two large concessionaires (ACESA and AUMAR) can be characterized as outliers (there being a close coincidence

[8] Benfratello et al. (2009) use the same output for a total cost function, Amdal et al. (2007) the total number of vehicles per year, Odeck (2008) annual traffic through tolls and Welde and Odeck (2011) the annual traffic through tolls divided by the number of lanes served. Although the output is not directly produced by the concessionaire, it is the best approximation.

between their mean and third quartile values). As for the price of inputs, the price of labor is around 29,000 € per worker, with a low standard deviation, while the prices of maintenance and capital are 94,741 and 136,339 € per kilometer, respectively, with a larger standard deviation. This is due to the existence of motorways with tunnels, where these price as expected increase sharply.

INSERT Table 1: Summary statistics

5. RESULTS

5.1. Regression results

The regression results of the model specified in Eq. 2 are presented in Table 2.[9] Since all variables are expressed in logarithms and normalized on the mean, the coefficients can be interpreted as elasticities. The original values of the monetary variables are deflated by a price index. A log-likelihood test confirms that a half translog is preferred to a Cobb-Douglas specification with the 1% significance level to the left.

INSERT Table 2: Stochastic estimates of total cost function parameter

The coefficients associated with the main variables present the expected sign and are statistically significant.[10] The only unexpected result is the non significant value of output. While it may seem surprising, it is well known that output (traffic demand) is mostly exogenous for a toll motorway company, with only part of it being dependent on the actions of the manager (See Engel, Fischer and Galetovic, 1997b; and Tirole, 1997, for a debate on toll motorway

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[9] This model has been implemented using Stata following Kumbhakar et al. (2015).

[10] A sensitivity analysis was conducted omitting the number of accidents with victims. The same results held not only in the case of the cost frontier parameter estimations, but also in that of the efficiency comparison (see subsection 5.2).

regulation and the commonly held view regarding the limited control on demand that toll motorway concessionaires have).

Motorway length is a significant and positive network parameter that affects the concessionaires' total costs – a one percent increase in total motorway length increases total costs by between 0.75 and 0.80%. This is also an expected outcome in the network industry, as total costs are higher if the network length is increased than if the total distance travelled by motorway users rises. The number of accidents with victims related to motorway traffic is non-significant in all models, indicating that the number of total accidents does not affect total motorway costs. The labor and maintenance input price elasticities are 0.14 and 0.27, respectively.

The time trend is negative and significant in all models, implying a 0.4% decrease in total costs each year. This result is in line with the outcome reported by Benfratello et al. (2009) with a 0.3-0.5 technological progress per year. In common with these authors, this can reasonably be accounted for in terms of the introduction of automatic toll systems, which reduce labor costs, and the increase in management experience obtained over time. However, given the relatively small values of the coefficients, they do not represent structural industry changes.

Table 3 shows that both economies of density and scale are present, which points to unexploited economies. The values, however, are higher for economies of density, indicating that an increase in the number of vehicles has greater effects than extending the motorway network. In other words, a more intensive use of a given motorway would lower the average cost considerably more than by extending it. However, recall that increasing the number of vehicle-kilometers is usually beyond the capabilities of the concessionaires. The variation across the parameters of economies of density can be attributed to the unobserved network effects, which are partially correlated with output and motorway length. We can confirm that economies of scale are only present on larger motorways as their operating costs are lower than those of small and medium-sized motorways.

INSERT Table 3. Scale and density economies

5.2. Efficiencies and policy changes

One of the reasons for estimating a stochastic cost frontier is to obtain the efficiency parameters. The value of the log likelihood ratio between the random and TRE model is 11.99, which is greater than the critical value of the statistic χ^2 with the 1% significance level to the left; the deviation from the frontier is, as such, not only due to noise. The parameter lambda (λ) indicates the ratio between the inefficiency terms and the random noise term. The value of u_{it} has to be positive in order to calculate the efficiency term. Likewise, if λ is statistically significant, there is evidence of cost inefficiency in the data. For all maximum likelihood estimation (MLE) models, this parameter is highly significant and positive. Table 4 presents the descriptive statistics of the efficiency estimates obtained from the different models.[11]

INSERT Table 4: Cost efficiency measures

This inefficiency is calculated as the excess costs of a given concessionaire in relation to those of the optimal concessionaire.[12] In general, most of the lower efficiency values are obtained with the random model and the Kumbhakar et al (2014) model on the persistent part, while the highest values are obtained on the remaining ones, which account for transient

[11] Efficiency in

[12] One assumption is that the exogenous variables do not directly influence the frontier. However, we have included the four dummies in the frontier in the random and true random effects models. Only regional governments increase concessionaire efficiency whereas privatization reduces it.

efficiency. This result is in line with results published elsewhere (Farsi et al., 2006).[13] In the efficiency part of the Pitt and Lee model and the persistent part of the Kumbhakar, Lien and Hardaker (2014) model, the unobserved firm-specific differences are interpreted as inefficiency, which suggests lower underestimated efficiency values. The TRE model separates the stochastic efficiency term from the firm-specific heterogeneity, adding a firm-specific term that captures this efficiency; the TRE model moves heterogeneity out of the efficiency estimate. The TRE model provides the same interpretation as that provided by the transient part of the Kumbhakar et al. (2014) model. The residual or transient efficiency is captured by both models, while allocative efficiency is captured by the Pitt and Lee model and the persistent part is captured by the Kumbhakar et al. (2014) model. The efficiency within the transient and persistent specifications are correlated, while between both groups there is no correlation (Table 5). Management efficiency is around 97-98%, while the structural problems in this sector represent an efficiency of around 92-95%. Indeed, once we have analyzed the mean efficiency and the correlation between models, the levels of efficiency are between 92-98%.

INSERT Table 5: Spearman rank-order correlations of cost efficiency

The efficiency estimation allows us to test whether or not there are differences in the efficiency values related to the characteristics of the various motorway concessionaires. To do so, we adopt as our statistical tool the Kruskal-Wallis test. This is a rank-based nonparametric that can be used to determine if there are statistically significant differences between two or more groups of a variable. The efficiency measure is an ordinal variable; therefore, we can test

[13] Another predicted result is the lower efficiency value (0.54 on average) for the fixed effects models. This result may be due to a correlation between the heterogeneity factors and the regressors. Whereas in the Pitt and Lee (1981) model the firm-specific effects are by construction uncorrelated with the regressors, these factors are suppressed at least partially through the "between" variations. For this reason, we do not present the fixed effects estimation.

whether the probability of a random observation from each group is equally likely to be above or below a random observation from another group. Unlike the ANOVA test of equality of means, the Kruskal-Wallis can be seen as a comparison of the mean ranks. However, the Kruskal-Wallis test does not provide the mean differences, which means a second test, such as the ANOVA test, is needed to confirm the mean value differences.[14] As post hoc tests are run to confirm where the differences occurred between groups, they should only be run when there is an overall significant difference in-group means. We summarize the results for the subsections that follow in Table 6. Recall that persistent efficiency (from the random model and Kumbhakar et al., 2014) is time invariant while transient efficiency (from TRE and Kumbhakar et al., 2014) is time variant.

INSERT Table 6: Mean efficiency and Kruskal-Wallis test on regulation and ownership

5.2.1. Price-cap scheme

Although initial toll prices depend on each specific concession contract and the winning bid, any price update is determined by a common regulatory framework for all concessions. Before 2001, national legislation introduced a general rule providing for automatic, yearly price adjustments based on inflation, a widely employed regulation in this industry (Iossa, 2015). This was reformed in 2001 with a shift to a more sophisticated price cap regulation (RPI-X). This more complex price regulation was introduced with an increase in the presence of private toll motorways due to the awarding of new concession awards and the plan to privatize the National Motorway Company (Albalate, Bel and Fageda, 2009). Even though a price cap formula was introduced, the typical X factor, which is commonly attributed to the target of

[14] This test has been used in efficiency mean group comparison, as in Stochastic Frontier Analysis in Farsi and Filippini (2004) or in transport services (Odeck, 2008b).

efficiency gains (Bernstein and Sappington, 1999; Sappington, 2002), was simply the deviation between the expected and real traffic received by each concession. Thus, to update the tolls, the new regulatory framework combined inflation and traffic deviations. Our expectation, nevertheless, is that the price-cap system should not impact concessionaire cost efficiency.

To analyze the impact of the regulation, we created a dummy variable that takes a value of one for years after 2001, and 0 otherwise. Although a price cap regulation affecting public utilities is usually expected to provide efficiency gains with respect to other forms of price regulation, the specific design of the X factor in the Spanish motorway industry does not necessarily provide incentives to improve productivity. According to the categories of tariff adjustment regulation proposed by Iossa (2015), this particular regulation lies somewhere between price cap regulation and banded rate regulation, given that tariffs are updated to take into account earning and risk sharing objectives due to traffic fluctuations, which are partly exogenous and beyond the control of the concessionaire.

Table 6 summarizes mean concessionaire efficiency for both groups and the mean difference results from the Kruskal-Wallis test on the price-cap scheme. We use time-varying efficiency since the introduction of the price-cap occurs at a specific point in time (2001). In the case of the transient efficiency models, introducing the price-cap scheme makes no improvement to cost efficiency.[15] Under an adjustment system based on inflation, concessionaires are fully protected from input price increases, while under price cap regulation their protection diminishes by the correction produced by the deviations between actual and predicted demand. Thus, it is not reflected in changes in concessionaire cost efficiency.

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[14] In order to capture the regulatory impact more accurately, we restricted the sample to the period 1998 through 2003 but found no change.

Although this result was as expected, a certain degree of caution should be shown given that we rely on a comparison conducted before and after the policy change without a dummy variable in the model. Indeed, part of this change could be captured by the linear time trend or by other non-linear time trends. Moreover, other unobservable characteristics that change over time may affect the result.

5.2.2. Central vs. regional granting authorities

An additional characteristic of the Spanish motorway industry is that it reflects the political decentralization of the State, so we find toll motorway concessions that have been awarded by either the central or regional authorities. Although toll motorway regulation falls under national legislation enacted by the Spanish Parliament (*Congreso de los Diputados*) – and, as a result, there are no major national differences in this respect – regional authorities can allocate resources, decide which projects are to be awarded, design the motorway technical project and specify the features of the concession contracts. Thus, efficiency differences may arise from the scope granted to the regional authorities by national legislation. In our sample, 9 of the toll motorway concessions were granted by regional/local governments: in percentage terms, 29% of our observations can be attributed to regional/local government concessions, while the remaining 71% are attributed to concessions granted by central government. Given this time-invariant characteristic, we created a dummy variable that takes a value of 1 if the motorway is promoted/granted by the central government authority and 0 otherwise.[16] We use time-invariant

[16] In our case, motorways not granted by the central government can only have been promoted by regional governments. We include as regional governments the *Diputaciones*, the public administration operating at the provincial level. This tier of administration lies between local and regional governments.

efficiency since the promoter of the motorway does not change over time and the tier of government is always the same.

Table 6 also shows the mean efficiency by group and the Kruskal-Wallis values for the persistent efficiency estimation. We find empirical evidence that motorways promoted by regional authorities are more efficient (2-5%) than those promoted by the central authority in all specifications. These results suggest that regional motorways are on average, slightly more cost-efficient than the motorways granted by the central government. However, when performing the same analysis for models in which efficiency does not absorb unobserved heterogeneity (TRE and KLH transient), we obtain non-statistical differences between groups for the two specifications. This result seems to support the argument that lower tiers of government allocate resources for motorways better, probably due to a better selection of projects and the avoidance of white elephants. Indeed, the current financial crisis in the industry in Spain only affects motorways awarded by the central government and, according to Albalate et al. (2015), their main problems are linked to project selection issues: route choices, overcapacity and above all, low actual demand.

All these elements have resulted in considerable gaps between capacity and demand, which in turn generate financial stress. This trend is easily identifiable in the descriptive statistics for our sample. Although regional motorways are more expensive per km, their revenues per km double those awarded by central government. Motorway concessionaires appointed by regional authorities have invested an average of 8.36 million € per km, while those appointed by the central government have invested just 6.82 million € per km. This difference (22.6 per cent) can be attributed to the poorer land conditions and the geological difficulties that regional motorways faced in their construction phase. Moreover, regional motorways receive higher volumes of road users recording an average of 0.898 million per km, whereas the central government motorway concessionaires receive an average of just 0.416. For Spanish PPP motorways, Garrido et al. (2017) find that the absolute total construction investment is not related to a concessionaire's economic performance.

5.2.3. Ownership models

Although the motorway industry in Spain is based primarily on private participation, there is some public participation in some of the concessionaires. The impact that public entities have as shareholders on efficiency can be tested in the same way as above, given that public sector control and presence could have an impact. Thus, we created a dummy variable that takes a value of 1 if there is public participation in a concessionaire in a specific year, and 0 otherwise. We used time-varying efficiency since both the public and private sector can acquire a concessionaire's shares over time, so that the distribution of these shares changes over time. Table 6 summarizes all the Kruskal-Wallis results from the transient specifications. For all specifications, we found no efficiency differences between public and private concessionaires. A shareholder with a majority control in a concession may be seen as a means of rescuing the most inefficient highways and while the participation of the public sector has changed over time, at certain points the public sector has been used to rescue a concession or government has participated in the management of a highway concession. Thus, there may well be structural factors that do not vary in time that account for public participation.

5.2.4 Privatization

Central government opted to nationalize various concessionaires in 1984 (Audasa, Aucalsa, Audenasa and Autoestradas), only for them to be fully or partially privatized again by public auction in 2003. We tested whether these respective ownership models present any differences in terms of their efficiency. In order to analyze the impact of privatization on management efficiency, we performed a Kruskal-Wallis test on the concessions that had been privatized. We created a dummy that takes a value of 1 if at least 50 per cent of shares are under private ownership following a prior period of public control and 0 otherwise. We compared concessionaires that have been privatized and, as a control group, companies that were fully public for the whole period. We used time-varying efficiency since privatization occurs in a specific period of time. Our results show that there are no cost efficiency differences between the two groups (Table 6). This result implies that privatization does not offer a better form of management.

Note that an endogeneity concern may arise here if the government opted to privatize those companies that were precisely the least efficient. In practice, the motives of central government were unrelated to efficiency goals, and they drew no distinction between the companies, all of which were privatized in a particular wave of a large-scale program involving public companies in all kinds of economic sector. Two primary motives underpinned the privatization program in Spain during the government of the conservative party (*Partido Popular*) led by José María Aznar. First, the aim was to obtain extraordinary revenues so as to meet the Maastricht convergence criteria for monetary union and, second, the party promoted an ideology of limiting the State role in the economy by transferring public assets to the private sector.

However, there is an additional concern here with regards to self-selection. If the motorways that had been nationalized in 1984 – and subsequently privatized in 2003 – were relatively more inefficient, then our results could be influenced by the structural efficiency problems of these motorways. Indeed, when we compare the levels of persistent efficiency of the motorways that were privatized with those of all the other motorways, we find that the former were less efficient than the rest. These results can be attributed to the fact that the motorways that were nationalized presented structural problems in their initial concession procedure or faced certain geographical difficulties, as shown by their levels of persistent efficiency. Thus, we can only confirm that privatization has failed to solve what are possibly non-systematic management problems of the public motorways and that private concessionaires have not been able to increase their efficiency following privatization.

6. CONCLUDING REMARKS

This paper has built an empirical model, applying the framework afforded by stochastic frontier analysis, in an attempt at identifying the cost efficiencies of Spain's toll motorway concessionaires and evaluating the role of ownership and regulation – and its reform. We have estimated both persistent and transient efficiency using the Pitt and Lee (1981), the true random effects and the Kumbhakar, Lien and Hardaker (2014) models. The estimates have been conducted on panel data for the years 1988 to 2015, controlling for different network characteristics.

Our main findings can be divided into two groups: the results of the frontier parameter estimation and those of the efficiency analysis. The first group of findings confirms the importance of technological progress as a source of sustained efficiency gains in conjunction with the presence of unexploited economies of scale and density. Here, we find the density economies to be much larger, indicating that increasing traffic is more relevant than extending the network. These results would seem to suggest that the fragmentation of the Spanish network, operated as it is by many concessionaires, has hindered the potential network effects and, hence, the exploitation of economies of scale and density. The current financial crisis faced by the Spanish industry has recently led to the nationalization of six concessions which are now managed under the same publicly owned corporation. According to our results, this could favor an industry that has been badly hit by overinvestment, overcapacity and overestimated demand. Although it is unrealistic to expect mergers in this highly regulated, atomized sector, further developments in the industry as it comes under public management should take into consideration the following lessons provided by this study: First, if the government wishes to privatize previously nationalized concessions (as occurred here in the early 2000s to the concessions nationalized in the early 1980s), it should award large concessions (i.e., comprising several motorways that previously were managed by separate concessionaires), to permit the exploitation of scale and density economies and avoid replicating the number of concessions prior to nationalization. Second, the forthcoming termination of various major concessions will provide the opportunity to evaluate their optimal size and to decide whether future concessions (if it is decided not to nationalize them) should retain the same number of motorways or not.

The second group of findings, concerning the efficiency analysis, is associated with ownership and the regulatory features of the sector. Here, there is no relation between transient and persistent efficiency; they differ in absolute numbers and the low correlations between them indicate that they measure two types of efficiency. According to our results, transient efficiency is greater than persistent efficiency because of the non-competitive environment of motorways and the allocation of inputs. Our findings suggest that the price cap regulation introduced in 2001 did not increase the transient cost efficiency, since, as expected, it does not affect the concessionaire cost structure. Better levels of persistent efficiency are found in the case of the concessionaires appointed by the regional authorities; however, no significant differences were found in management efficiency across tiers of government. Lower tiers of government (regional), in their role as granting authorities, seem to allocate resources for motorways better than central government, which probably reflects their ability to select viable projects and to avoid white elephants. Regional motorways are more expensive per km during the building phase, mainly due to geographic characteristics; however, their revenues per km double those of motorways awarded by central government. Note that all the concessionaires presenting signs of financial stress were appointed by central government. We also analyzed the role of ownership and no differences were detected between public and private ownership models. Motorway concessionaires that were subsequently privatized have not increased their transient efficiency, failing to lend support for efficiency gains achieved through privatization. However, levels of persistent efficiency were lower in privatized motorways, suggesting that these motorways were nationalized due precisely to these lower levels. Yet, what this seems to demonstrate is the difficulties involved in increasing managing efficiency – both for public and private managers – because part of the inefficiency remains once a motorway has been built. Note, nevertheless, that this finding needs to be treated with caution given the small sample considered here.

Our results offer interesting insights for policy makers. Given the current restructuring of the industry with the nationalization of the bankrupt concessions and the forthcoming expiry of contracts, the debate as to which ownership model offers the best outcomes is likely to reemerge. Our findings do not identify any advantages of private ownership in terms of cost efficiency, rather they show that the most important aspect for the efficiency of a motorway is project selection – that is, whether or not a motorway should be built, and how and where it should be built – rather than the ownership of the managing company. In short, greater attention should be given to the economic and financial evaluation of projects than to how it should be managed. To have quality PPP policies in the adoption phase, countries need to have well developed institutions (Rosell and Saz-Carranza, 2019).

All in all, this paper demonstrates the power of cost stochastic frontier panel data techniques as a tool not only for measuring efficiency but also for evaluating public policies in terms of their efficiency outcomes. Besides this, our main results on regulatory and ownership reforms provide highly pertinent insights for policy makers. It is our firm belief that the methodologies that separate both types of efficiency offer great potential to regulators and policy evaluation bodies working in the field of transportation. Although few studies of this kind (i.e. in which two types of efficiency are measured) have been reported to date, we expect to see considerably more in the future, given their huge potential for refining the analysis and evaluation of public policy efficiency.

Finally, we should identify some of the limitations of our study. We have supposed that motorway concessionaires of different ownership types have the same technology. Compared with other industries, this is not a major supposition to make; however, the model cannot explain the determinants of efficiency. Unless efficiency levels can be systematically changed by modifying the policy variables, our results are more descriptive than those on the impact evaluation side.

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TABLES

Table 1*: Summary statistics*

Variables	Mean	Standard deviation	1st quartile	3rd quartile
Total costs (million €)	28.5	37.4	8	30
Price of labor (€)	29,018	10,974	20,751	35,619
Price of maintenance (€)	94.741	99,972	42,847	96,137
Price of capital (€)	136,339	141,500	49,464	165,369
Number of workers	206.35	271.35	69.5	220
Capital invested (million €)	596,000	591,000	229,000	832,000
Vehicle-kilometers (million km)	846	1440	121	805
Length (km)	124.89	138.68	43.1	112.6
Number of accidents with victims per veh·km	$7.89 \cdot 10^{-8}$	$6.76 \cdot 10^{-8}$	$3.60 \cdot 10^{-8}$	$9.32 \cdot 10^{-8}$

Note: All monetary values are in 2002 euros

Table 2*: Stochastic estimates of total cost function parameter*

Variables	Random model (Pitt and Lee, 1981)		True Random Effects		Kumbhakar, Lien and Hardaker (2014)	
	Coefficients	Standard error	Coefficients	Standard error	Coefficients	Standard error
β_{PL}	0.149***	(0.00674)	0.137***	(0.00785)	0.150***	(0.00686)
β_{PM}	0.271***	(0.00405)	0.272***	(0.00419)	0.270***	(0.00413)
β_{Y}	0.056	(0.17536)	0.181	(0.14374)	0.156	(0.20010)
β_{LEN}	0.802***	(0.0500)	0.768***	(0.00385)	0.753***	(0.04983)
β_{ACC}	0.039	(0.00743)	0.049	(0.03214)	0.025	(0.03514)
β_{T}	-0.0044***	(0.00044)	-0.0043***	(0.00044)	-0.0041***	(0.00047)
β_{PLPL}	0.030***	(0.00486)	0.021***	(0.00614)	0.031***	(0.00492)
β_{PMPM}	0.079***	(0.00322)	0.084***	(0.00384)	0.079***	(0.00331)
β_{YY}	-0.021	(0.17452)	-0.138	(0.14440)	-0.135	(0.19956)
β_{LENLEN}	0.026	(0.05110)	0.074**	(0.03650)	0.310	(0.40764)
β_{ACCACC}	0.036	(0.03374)	0.045	(0.03120)	0.022	(0.03424)
Constant	0.0336***	(0.0143)	-0.1054***	(0.0115)	0.0342**	(0.0171)
σ_u	0.1055***	(0.0164)	0.0228***	(0.0023)		
σ_v	0.0312***	(0.0012)	0.0211***	(0.0015)		
$\lambda = \sigma_u^2/\sigma_v^2$	3.384***	(0.0163)	1.083***	(0.0032)		
Log likelihood	695.97		701.97			
Observations	451		451		451	

Significance levels: * 10%; **5%; *** 1% (standard errors are presented in parentheses).

Table 3. Scale and density economies

	Economies of density			Economies of scale		
	ED (RE model)	ED (TRE model)	ED (KLH)	ES (RE model)	ES (TRE model)	ES (KLH)
10th	12.268	1.839	2.999	1.144	0.933	1.145
25th	13.817	3.100	3.793	1.154	0.983	1.109
50th	17.397	4.887	5.878	1.164	1.077	1.150
75th	21.231	8.347	10.064	1.176***	1.128**	1.162**
90th	24.399	13.412	14.961	1.191***	1.167***	1.078***

Standard errors in parentheses *** $p<0.01$, ** $p<0.05$, * $p<0.1$

Table 4*: Cost efficiency measures*

Model	**Mean**	**Standard Deviation**	**Minimum**	**Maximum**
Random model	0.9541	0.034	0.8669	0.9956
True Random Effects	0.9719	0.0160	0.8736	0.9953
KLH (2014) transient	0.9823	0.0067	0.9414	0.9951
KLH (2014) persistent	0.9232	0.0635	0.7094	0.9951

Table 5: Spearman rank-order correlations of cost efficiency

Model	Random model	Kumbhakar, Lien and Hardaker (persistent)	True Random Effects	Kumbhakar, Lien and Hardaker (transient)
Random model	1.000			
Kumbhakar, Lien and Hardaker persistent	0.777	1.000		
True Random Effects	0.170	0.175	1.000	
Kumbhakar, Lien and Hardaker transient	0.093	0.083	0.961	1.000

Table 6. *Mean efficiency and Kruskal-Wallis test on* regulation and ownership

Model	Price-cap regulation			Granting authority		
	Mean efficiency		χ_1^2 value (p-value)	Mean efficiency		χ_1^2 value (p-value)
	$D_{pricecap}$=0 (n=83)	$D_{pricecap}$=1 (n=368)		$D_{central}$=0 (n=116)	$D_{central}$=1 (n=335)	
True Random Effects	*0.9676*	*0.9807*	*2.143* *(0.1432)*			
Kumbhakar, Lien and Hardaker (2014) Transient	*0.9719*	*0.9824*	*0.480* *(0.4886)*			
Random model (Pitt and Lee)				*0.9621*	*0.9410*	*159.695* *(0.0001)*
Kumbhakar, Lien and Hardaker (2014) Persistent				*0.9522*	*0.9099*	*109.873* *(0.0001)*

Model	Public ownership			*Privatized*		
	Mean efficiency		χ_1^2 value (p-value)	Mean efficiency		χ_1^2 value (p-value)
	D_{public}=0 (n=389)	D_{public}=1 (n=62)		$D_{privatized}$=0 (n=38)	$D_{privatized}$=1 (n=16)	
True Random Effects	*0.9720*	*0.9718*	*0.661* *(0.4163)*	*0.9754*	*0.9742*	*0.001* *(0.9315)*
Kumbhakar, Lien and Hardaker (2014) Transient	*0.9822*	*0.9825*	*0.481* *(0.4880)*	*0.9828*	*0.9829*	*0.210* *(0.6466)*
Random model (Pitt and Lee)	*0.9537*	*0.9563*	*2.678* *(0.1018)*	*0.9552*	*0.9487*	*22.174* *(0.0001)*
Kumbhakar, Lien and Hardaker (2014) Persistent	*0.9196*	*0.9379*	*1.132* *(0.2874)*	*0.9241*	*0.9195*	*8.811* *(0.0030)*