

LOGISTIC PLATFORMS AND EFFICIENCY OF ROAD HAULAGE
IN EUROPE (2004-2012)

*PLATAFORMAS LOGÍSTICAS Y EFICIENCIA EN EL TRANSPORTE DE
MERCANCÍAS EN EUROPA (2004-2012)*

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ABSTRACT

This paper analyses the technical efficiency of European road freight transport companies over the period 2004-2012. The results show that road freight companies that use logistic platforms appropriately are more efficient. Other interesting results were also obtained showing that the liberalisation of transport sectors, inventory management and the use of Information and Communications Technology all lead to improvements in companies' technical efficiency.

Keywords: Stochastic Frontier; Technical Efficiency; Production Functions; Road Haulage.

RESUMEN

Este trabajo analiza la eficiencia técnica de las empresas europeas de transporte de mercancías por carretera durante el período 2004-2012. Los resultados muestran que las empresas de transporte de mercancías por carretera que utilizan plataformas logísticas adecuadamente son más eficientes. Otros resultados interesantes también fueron obtenidos corroborando que la liberalización de los sectores del transporte, la gestión de inventarios y el uso de las Tecnologías de Información y Comunicaciones lleva a mejoras en la eficiencia técnica de las empresas.

Palabras clave: Fronteras estocásticas; Eficiencia técnica; Funciones de producción; Transporte por carretera.

JEL Classification: C23, L90, L91, O18.



1. INTRODUCTION

The study of the transport sector is a major challenge for economists. Its specific characteristics make it conducive to the study of many classical economic problems, such as externalities, potential economies of scale and sunk costs, its spatial nature, the impossibility of product storage, economies of density and peak and slack demand periods, among others.

The European Union (hereinafter the EU) internal market for transporting freight by road has been reformed in the past thirty years (the liberalisation of the sector). The EU has progressively established a comprehensive set of uniform rules to ensure fair competition between road transport operators and to ensure a homogeneous national regulatory framework for its member states.

As stated in the 10371/14 Council of the EU, the EU open internal market has made it possible for transport companies to supply services across national borders with a set of common rules applicable to all operators.

The study of a European road haulage market and its distinctive features inspired this piece of research, in which we estimate the Technical Efficiency (hereinafter TE) of the European road haulage sector during the period 2004-2012.

This work continues, at the European level, the line of research undertaken by Baños-Pino *et al.* (2005) on the estimation of efficiency of road transport companies. In the study by Baños-Pino *et al.* (2005), TE was estimated for different sub-sectors of the Spanish road freight transport sector, including full-load transport, group services, international freight, tank transport, refrigerated transport, special carriage and crane transport. However, it was not possible to differentiate by sub-sectors in this research, because the information from the database AMADEUS does not distinguish between sub-sectors.

The second section comprises a literature review. In the third section, we will introduce the theoretical models for measurement of TE based on stochastic frontier methods. The fourth section offers a summary of the main statistics of the data. In the fifth section, we will show the results of empirical estimates of TE. Finally, the sixth section outlines the main conclusions of this research.

2. LITERATURE REVIEW

Freight transport has received much less attention in the economic literature than passenger transport. Authors like Ortúzar and Willumsen (2001) point

out that this is because passenger transport involves fewer stakeholders and is therefore less complex to model. Freight transport involves more agents and other particular features, such as storage, making it more difficult to model and estimate accurately. Passenger transport is often modelled from the theory of consumer behaviour, while freight is modelled from the theory of the company. In the case of passengers, the maximisation of the utility of a passenger is modelled subject to the constraint of budget, and optimisation of this program or its dual expenditure minimisation yields the relevant economic functions. Freight transport is usually modelled from the behavioural theory of the company, particularly from the production and costs theory. Also, in freight transport, the company's cost minimisation is modelled subject to the constraint of a production level, and this program or its dual output maximisation yields the relevant economic functions. This is the most common approach because freight transport companies provide services to other companies which require their freight services. Freight transport is therefore a productive input within a company's cost minimisation process.

Winston (1983) and Borra (2004) classify empirical studies of freight transport into modelling studies with aggregated and disaggregated models. Oum (1979a, 1979b) uses aggregate models of total cost functions, with constant returns to scale, imposing strict separability between transport output, its price and other productive inputs. Friedlaender and Spady (1980) conduct a study with aggregated models, using variable short-term cost functions to study freight transport. Other aggregated works, such as those by Westbrook and Buckley (1990), Bianco *et al.* (1995), and Borra (2004), use changes in the transcendental logarithmic functional form for total costs with the intention of improving the regularity conditions of this function.

Following Borra (2004), there are also works belonging to these aggregated models which directly estimate demand functions for the freight transport mode studied, such as those by Hsing (1994), Kulshrestha *et al.* (2001) and Coto-Millán *et al.* (2005a). These works tend to relate the total quantity of freight transported via the corresponding mode of transport with the price of the freight service, the prices of competing modes of transport and the level of GDP of the country or region. The works by Coto-Millán *et al.* (2005a) relate the total quantity of freight transported via the corresponding mode of transport to: the price of the freight service, the price of the goods transported, the price of competing modes of transport and the GDP of the country or region for import functions and the GDP of the demanding countries or regions for export functions. Conditional demand aggregated functions for freight transport are estimated for a country or region, or applied to international trade. These works distinguish between the short and the long term in their estimates and thus obtain cross-price elasticities of demand for products in the short and long term.

Disaggregated models use data corresponding to individual companies. Production and cost functions are modelled from data of individual companies. In this line, the works of Eastman (1980), Jara-Díaz (1982), Witlox *et al.* (2005)

and Pan (2006) are of great interest. In disaggregated models, freight demand functions are also modelled with a behavioural approach, such as in Winston (1981), Daughety *et al.* (1981), Jiang *et al.* (1999), and Shinghal *et al.* (2002), and with a logistic approach, such as in Roberts *et al.* (1984), McFadden *et al.* (1985), Inaba *et al.* (1989), Abdelwahab *et al.* (1992), Abdelwahab (1998) and Batarliene *et al.* (2011).

There is also rich literature on efficiency arising from the early work of Farrell (1957) with numerous applications in the fields of banking, agricultural production and transport. In particular, we have analysed the economic efficiency in the bulk shipping industry in the research of Tolofari *et al.* (1987) and the technical efficiency of ports in the work of Tongzon (1993), Baños *et al.* (1999) and Cullinane *et al.* (2006). González *et al.* (2009) offers an excellent review of this literature. The effects of network economics of high-speed rail is analysed in the research of Coto-Millán (2007a). The technical efficiency of major global airlines is analysed in the work of Coelli *et al.* (1999) and Buhalis (2004). Buhalis (2004), based on surveys and qualitative analysis, studies the effects of ICT on the results and efficiency of airlines and concludes that the effects are clearly positive. The TE of airport activity is analysed in Inglada *et al.* (2004) and the TE of low-cost airports for low-cost airlines is analysed by De Neufville (2008).

There is very limited literature on the efficiency of road freight transport. As far as we know the first piece of research in the field is that of Baños-Pino *et al.* (2005), which studies the TE of Spanish road transport firms unbundled into six specialised sub-sectors with six panels of data for the years 1994-1997. The study concludes that the road freight transport sector in Spain has an average efficiency of around 65%, with a variability of between 40% and 80% depending on the sub-sector. In addition, the work by Bhagavath (2006) studies forty-four state-owned road freight transport companies using the Data Envelopment Analysis (DEA) method for the years 2000-2001 and concludes that only eight firms operate with a considerable level of TE.

Davies *et al.* (2007) examines the extent to which Internet freight exchanges and the use of information and communication technology (ICT) processes are affecting general haulage. The authors conclude that while many of the smaller haulage operators remain dependent upon traditional communication and process systems, the larger logistics companies, who control the majority of vehicles and freight movements, are progressively developing new ways of working supported by ICT adoption.

More recently, the work by Markovits-Somogyi (2012) analyses the major freight firms in Hungary using the DEA method.

Continuing in the vein of these studies, an efficiency analysis using Stochastic Frontier Analysis (hereinafter SFA) for the main European road freight transport companies in the period 2004-2012 is provided below.

3. ESTIMATION STRATEGY TO MEASURE TECHNICAL EFFICIENCY

In order to measure company-specific efficiency, we apply models which allow for time-varying inefficiency, in line with Battese and Coelli (1995)¹ and Greene (2005a, 2005b). The models differ in their ability to account for unobserved and observable heterogeneity, and, hence, model comparisons allow for an analysis of the effect of different kinds of heterogeneity on efficiency estimates.

The starting point was the model proposed by Battese and Coelli in 1995 (hereinafter BC95). In the BC95 model, the function which explains inefficiency is estimated in a single step with production technology, which avoids the problem of inconsistency of a two-stage estimation process. Wang and Schmidt (2002) have cautioned against the two-step procedure to calculate the effect of the measured covariates, the 'z's', on estimates, arguing that the omission of the covariates at the 'first step' is tantamount to the omitted variable problem in ordinary regression. Nonetheless, this procedure is common, and, indeed, is routine in the DEA literature.

The BC95 model can be expressed as:

$$Y_{it} = \alpha + \sum_{j=1}^k \beta_j X_{jit} + \varepsilon_{it} \quad , \varepsilon_{it} = V_{it} - U_{it} \quad , i=1, \dots, N, t=1, \dots, T, \quad (1)$$

In (1), Y_{it} denotes (the logarithm) of production of the i -th company in the t -th period; X_k represents the k -th (transformation) of input quantities; β_j represents the output elasticity with respect to the j -th input; V_{it} is a random variable assumed to be iid $N(0, \sigma_v^2)$, and independently distributed of U_{it} which has the following specification:

$$U_{it} = z_{it} \delta + R_{it} \quad (2)$$

In (2), U_{it} represents the technical inefficiency effect on production and is also assumed to be iid with truncations at zero of the $N(\mu, \sigma u^2)$.

z_{it} is a vector ($1 \times m$) of company-specific covariates accounting for observable heterogeneity (see Greene 2008 for more details) and associated with the technical inefficiency of production of the companies over time. The explanatory variables may include some input variables in the stochastic frontier, provided that the inefficiency effects are stochastic. If the first z -variable is one and the coefficients of all other z -variables are zero, then this case represents the model specified in Stevenson (1980) and Battese et Coelli. (1992).

¹ See Coelli *et al.* (2005) for an in-depth explanation of the model and Olsen and Henningsen (2011) for the right interpretation of marginal effects of the z 's variables on technical efficiency when estimating the translog production function.

The δ variable is a vector ($m \times 1$) of unknown coefficients. If all elements of the δ vector are zero, then the technical inefficiency effects are not related to the z variables and the half-normal distribution originally specified in Aigner *et al.* (1977) is obtained.

The R_{it} variable is a random variable $N(0, \sigma^2)$, but is not necessarily identically distributed. The term U_{it} is the non-negative truncation the distribution $N(z_{it} \delta, \sigma_u^2)$; $z_{it} \delta$ is the average of the normal distribution, which is truncated to zero to obtain the distribution of U_{it} . The fact that U_{it} is non-negative does not mean it is necessarily positive for each observation.

The TE of production for the i -th company in the t -th observation is defined by the equation: $TE_{it} = \exp(-U_{it}) = \exp(-z_{it} \delta - R_{it})$. The maximum likelihood method is proposed for the simultaneous estimation of the parameters of the stochastic frontier and the model for the technical effects of inefficiency.

Greene (2004) warns against the inappropriate treatment of heterogeneity, which could distort estimates of inefficiency, and categorises heterogeneity into observable heterogeneity (environmental factors that are beyond companies' influence) and unobserved heterogeneity (factors that are not identifiable in terms of companies' quality performance). Greene (2005a) presents a "true" random effects (hereinafter TRE) model approaching this issue through a time-varying model with unit-specific intercepts, obtained by replacing (1) with the following specification:

$$Y_{it} = (\alpha + W_i) + \sum_{j=1}^k \beta_j X_{jit} + \varepsilon_{it}, \quad \varepsilon_{it} = V_{it} - U_{it}, \quad i=1, \dots, N, \quad t=1, \dots, T, \quad (3)$$

$$W_i \sim N(0, \theta^2)$$

where W_i is a time-invariant and company-specific random term, assumed to be uncorrelated with everything else in the model, meant to capture unobserved heterogeneity. θ represents the standard deviation of the unobserved heterogeneity.

We define V_{it} , U_{it} as per the BC95 Model.

This TRE model is fit by maximum simulated likelihood methods. Compared to the BC95 model, this specification allows for time-varying inefficiency to be disentangled from unit-specific time-invariant unobserved heterogeneity.

4. DATA AND VARIABLES

The data set used in this study is an unbalanced panel of 137 road haulage companies for the period 2004-2012. The data came from the annual accounts filed with each country's Companies Register. The AMADEUS database, managed by Bureau van Dijk, provides the necessary data on each European company for the period studied.

This panel displays information on the input used by each company in different years, representing the output produced as *A.V.* (Added Value). The capital

factor of each company is called *Capital*, the number of workers is referred to as *Labour*, and the factor representing intermediate consumption is called *IC*. In addition to the primary variables of the study, we have information on the GDP deflator, which has been used to express the data on GDP, capital and intermediate consumption in real terms.

The descriptive statistics for each variable, following deflation, are presented in Table 1.

TABLE 1: SUMMARY STATISTICS

Num. of companies	Num. of Observ.	Variable	Mean	Standard Deviation	Minimum Value	Maximum Value
137	1147	A.V.	59,389	131,267	22	1,215,639
		Capital	37,734	82,316	19	747,790
		Labour	1,362	3,074	3	29,050
		IC	104,874	255,808	6	2,741,110

Notes: Output (A. V.), capital (K) and Intermediate Consumption (IC) are in thousands of euros.

The AMADEUS database was sufficient to cover data on companies from twenty-one countries across the European area². It is noteworthy that, to date, all the home states of the sample companies are EU members or have bilateral agreements with the EU. Table 2 shows the sample division by the European subregion of the companies' home states.

TABLE 2. SAMPLE DIVISION (BY EUROPEAN SUBREGIONS)

	Num. of Companies	Mean (A.V.)	St. Dev. (A.V.)
Northern Europe	40	98,698	174,553
Western Europe	28	82,099	181,025
Eastern Europe	27	8,884	18,237
Southern Europe	42	33,043	35,048

Classification based on the United Nations Statistics Division.

Source: Prepared by the authors

Table 3 shows the variables included as *z*'s explanatory variables to model the mean of the inefficiency term, and the signs expected for each variable.

² Regarding the choice of the sample, the criterion followed has been the availability of comprehensive data of the Amadeus database. We have selected those firms in the Amadeus database reporting data for all years in order to have a panel data as balanced as possible.

TABLE 3: LIST OF EXPLANATORY VARIABLES

Variable	Vble. Type	Measurement	Expected sign
Logistic ¹	Dummy	1 = Logistic services, 0 = Otherwise	Negative
Stock management	Value	Logarithm of inventory turnover ratio	Positive
Use of New Technologies	Value	Logarithm of internet users (per 100 people)	Negative
ITC Imports	Value	Logarithm of Information and Communications Tech- nology imports	Negative
Degree of disperse population	Value	Logarithm of (rural popula- tion/total population)	Positive
Level of EU market integration	Value	Logarithm of years of EU membership	Negative
Fuel Price	Value	Logarithm of Pump price for diesel (US\$ per litre)	Positive

Source: Prepared by the authors.

The variables in table 3 were selected according to the Structure-Conduct-Performance model proposed by Bain and Mason of Harvard. Therefore, the variable corresponding to Results is the technical inefficiency variable which we seek to explain from Structure variables such as the country variables (*Degree of disperse population*, *Level of EU market integration* and *Fuel Price*) and from Conduct variables such as Company Management Variables (including *Logistics* and *Stock management*) and Innovation Variables (*Use of New Technologies* and *ITC Imports*).

We expect productive specialization to have a positive effect on sector efficiency. We therefore believe that specialized firms providing logistic services will have, on average, a higher level of efficiency and therefore a negative sign.

The *Stock management* variable measures the number of times inventory is sold and restocked each year. We expect a high value of this variable to be associated with a lower level of inefficiency. This may be related to the ability of the company to efficiently manage storage and is therefore also related to improvements in logistics.

The use of new technologies should have a positive impact on sector efficiency, so the *Use of New Technologies* and *ITC Imports* variables should have a negative sign.

The same reasoning may be applied to the expected signs (positive, negative, positive) for the last three variables.

5. RESULTS

To estimate the production function, from which efficiency scores are obtained, we take the translog specification (hereinafter translog) as a starting point. The translog function is a more flexible extension of the Cobb-Douglas function and therefore does not require a constant and unitary elasticity of substitution. Table 4 shows the estimated coefficients of the BC95 and TRE models. Presented on the right, in brackets, are the standard errors. The first order coefficients in Table 4 can be identified as production elasticities evaluated at the sample means³. *Capital*, *Labour* and *IC* are statistically significant and have the expected signs.

TABLE 4: SFA ESTIMATION (PERIOD 2004-2012)				
	BC95	Model	TRE	Model
Variable	Coeffic.	Std Error	Coeffic.	Std Error
Capital	0.2231	(0.010)***	0.1322	(0.012)***
Labour	0.7034	(0.012)***	0.6370	(0.014)***
IC	0.0223	(0.008)**	0.1429	(0.011)***
Capital ²	0.1922	(0.019)***	0.0293	(0.020)
Labour ²	0.2787	(0.034)***	0.1782	(0.036)***
IC ²	0.0049	(0.016)	0.0300	(0.014)*
Capital*Labour	-0.1824	(0.022)***	-0.0520	(0.018)**
IC*Capital	-0.0404	(0.011)***	-0.0116	(0.010)
Labour*IC	-0.0324	(0.015)*	-0.0795	(0.014)***
Constant	4.3851	(0.011)***	4.3073	(0.020)***
σ^2	0.3813	(0.010)***	0.2169	(0.007)***
γ	0.7845	(0.000)***	0.4756	(0.000)***
σ_v^2	0.2502	(0.016)***	0.1535	(0.010)***
σ_μ^2	0.1311	(0.005)***	0.0634	(0.003)***
θ			0.2392	(0.012)***
TE Effects	BC95	Model	TRE	Model
Variable	Coeffic.	Std Error	Coeffic.	Std Error

³ In order to be able to interpret the first-order coefficients of the (logarithmic) input quantities as output elasticities at the sample mean, we use the mean-scaled output quantities.

Logistic	-0.1421	(0.034)***	-0.1818	(0.052)**
Stock management	0.0384	(0.056)	-0.0911	(0.058)
Use of New Technologies	-0.5321	(0.096)***	-0.1653	(0.066)*
ITC Imports	0.0015	(0.005)	-0.0228	(0.006)***
Degree of disperse population	0.3060	(0.140)*	0.1820	(0.119)
Level of EU market integration	-0.3856	(0.032)***	-0.1787	(0.025)***
Fuel Price	0.5670	(0.105)***	0.2138	(0.064)**
Constant	0.5182	(0.277)''	0.3593	(0.237)
Log (likelihood)	309.61		732.55	

All maximum likelihood estimates of the models are obtained by using the software Stata 13.0 and R version 3.0.3, Frontier package made by Coelli, T. and Arne Henningsen (2013).

Signif. codes: 0 '***', 0.01 '**', 0.05 '*', 0.10 ''

The parameter $\gamma = \sigma_u^2 / (\sigma_v^2 + \sigma_u^2)$ lies between zero and one and indicates the size of the inefficiency term. If γ is zero, the inefficiency term U is irrelevant. In contrast, if γ is one, the noise term V is irrelevant and all deviations from the production frontier are explained by technical inefficiency. That is, between 48 to 78 percent of total variations (depending on the model) in production are due to technical inefficiency. This implies that the degree of random error in total variations in production is small.

In the TRE model, the parameter θ (standard deviation of unobserved heterogeneity) is statistically significant, confirming the presence of unobserved heterogeneity.

Both the BC95 model and the TRE model account for the impact of z 's explanatory variables on estimates of $E[U|\mathbf{z}]$ or $E[\exp(-U)|\mathbf{z}]$ by allowing the inefficiency mean to be a function of z 's variables.

In both the BC95 model and the TRE model five out of the seven covariates are found to be significant. Four of them (*Logistics*, *Use of New Technologies*, *Level of EU market integration* and *Fuel Price*) have the same sign in both models and are in line with the expected sign.

The interpretation is that the more involved companies become in logistics activities, the more efficient they will be. In fact, as shown in Table 5, companies operating in a traditional road freight transport model are, on average, less efficient than companies using logistic platforms.

On the contrary, we cannot confirm that increases in the number of times inventory is sold and restocked each year are correlated to increases in the efficiency level.

The following variables were also included as Conduct variables: *Use of new technologies* and *ICT imports*. The interpretation of the results is that the

greater the *use of new technologies*, the more efficient companies are and the higher the *ICT imports* in each European country, the more efficient, or less inefficient, companies in that country are (the *ICT imports* variable is only significant in the TRE model).

With regard to the Structure variables, it should be noted that the greater the degree of population dispersion, the more inefficient transport companies are. Furthermore, the more the country is integrated into the European Union, the greater the road transport liberalisation and the greater the efficiency of companies. Finally, the more fuel prices increase, the more inefficient companies are. Further increases in fuel tax are not welcomed by the sector.

Table 5 shows the comparative progression of the TE of road transportation companies by model. Estimates of the TE of companies that use logistic services versus traditional transportation companies is also shown.

Results show that the average TE of the European road freight transport sector ranges from 0.79 to 0.86 depending on the model (BC95 and TRE respectively). It is further observed that road freight companies that use logistic platforms are up to 14-17% more efficient.

Steady growth in TE scores was observed until 2007. From 2007 to 2012 (coinciding with the economic downturn) TE scores fell by 2.5% in the sector.

Year	BC95	TRE
2004	0.772	0.846
2005	0.779	0.856
2006	0.791	0.869
2007	0.800	0.874
2008	0.793	0.861
2009	0.795	0.865
2010	0.795	0.866
2011	0.792	0.865
2012	0.782	0.852
TE (Average)	0.789	0.862
Logistic companies	0.841	0.908
Non-logistic companies	0.718	0.799

Source: Prepared by the authors.

6. CONCLUSIONS

This research found, as its main conclusion, that the average Technical Efficiency of the European road freight transport sector ranges from 0.79 to 0.86 depending on the model (BC95 and TRE respectively).

A second conclusion was that the impact of the use of logistic platforms on technical efficiency is positive and significant (up to 14-17% difference in TE).

A third conclusion was that the liberalisation/deregulation of the European road freight transport market has positive effects on the technical efficiency of companies. Therefore, the efficiency of companies from countries which were pioneers in joining the EU open internal market is greater than that of those from countries that took longer to join.

A fourth conclusion was that an increase in the dispersion of the population in European countries has decreased the technical efficiency of European road freight transport companies.

A fifth conclusion was that the successive increases in oil prices from 2004 to 2012 had a negative effect on the technical efficiency of European freight transport companies. Further increases in fuel tax would damage the efficiency of the sector.

A sixth conclusion was that road freight transport companies that make greater use of new technologies are more efficient than those which use them less.

A seventh conclusion was that countries with higher ICT imports have more efficient European road freight transport companies than those which import less.

The above findings are significant in terms of furthering road freight transport deregulation and liberalisation policies in Europe. The findings are also significant in terms of increasing investment in technological development in the sector. This is the main recommendation of this research in terms of policy.

Furthermore, the research gave rise to three recommendations for road freight transport companies. The first is to take note of the new business model with higher use of logistic platforms, as these significantly increase technical efficiency.

A second recommendation is that traditional road freight transport companies should be more involved in the use of ICT.

A third recommendation is for companies to focus their efforts on better managing their stock if they want to increase their efficiency.

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