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THE IMPACT OF PUBLIC TRANSPORT POLICIES ON THE EFFICIENCY OF OPERATING COMPANIES: A COMPARISON BETWEEN EUROPEAN COUNTRIES

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ABSTRACT.* Achieving sustainable mobility is widely regarded as one of the major challenges in contemporary public management. Governments must lead policies that facilitate progress towards sustainable, accessible, and efficient mobility. The European Union (EU) has identified the attainment of sustainable mobility as a key objective, with the first White Paper on transport being published in 1992. The main EU member states have implemented this roadmap to varying extents via different regulatory frameworks. In urban and metropolitan areas of large cities, the need to develop comprehensive mobility policies is particularly evident, as these areas face substantial challenges pertaining to environmental impact, public health, accessibility, and economic management. The governance of interurban transport (both passenger and freight) must also address these challenges while fostering social and territorial inclusion. In both cases, the transition towards a new paradigm of sustainable mobility necessitates a reduction in private vehicle usage and the promotion of a public transport system. This sector is crucial to the economy, accounting for nearly 10% of the EU's gross value added and generating approximately 11 million jobs. Transport policies directly impact operators in the sector across multiple dimensions, including management, efficiency, profitability, and investment planning. Therefore, this study aims to analyse the impact of transport policies on the efficiency of urban and suburban transport companies in EU countries. The methodology employed consists of (1) a description of the main variables of these companies, (2) a Data Envelopment Analysis and Malmquist Index to provide statistical inference estimators for productivity, Efficiency Change (EFCH) into Pure Technical Efficiency Change (PTECH), and Scale Efficiency Change, and (3) a regression analysis linking efficiency to transport policies in the EU country members.

The present study contributes to the academic literature and proposes theoretical and practical implications for the various stakeholders involved in the management of the transport sector.

KEYWORDS: public transport, efficiency, transport policies, sustainability, data envelopment analysis, European Union.

JEL classification: R40, R48, Q01, C61, R58, M10.

Introduction

Achieving efficient and sustainable mobility is widely regarded as one of the major challenges in public sector management across all countries, particularly in Europe, where transport policies have evolved significantly in recent decades. These policies have primarily focused on key aspects such as sustainability and urban mobility. The present paper aims to assess the efficiency of transport companies in the four largest EU countries by applying Data Envelopment Analysis (DEA). The main hypothesis to be tested in this study is proposed:

H1: Technological differences and transport policy variations significantly affect the overall efficiency of firms in the major EU countries.

With regard to transport and sustainability policies in the countries analysed, the European Union (EU) has developed coordinated measures aimed at integrating transport policy with environmental objectives, in order to reduce its negative impact (Pyza et al., 2019; Gudmundsson et al., 2015). The EU White Paper entitled "Roadmap to a Single European Transport Area – Towards a Competitive and Resource Efficient Transport System" (COM (2011) 0144) outlines the principles and main strategies of EU transport policy along four key axes (integration, innovation, infrastructure, and internationalisation):

- Establishment of a single European transport area;
- Urban transport: halving conventionally-fuelled vehicles in cities by 2030, and phasing them out entirely by 2050;
- Energy efficiency: promoting the use of renewable energy sources in transport;
- Encouragement of a competitive transport policy that stimulates economic growth;
- Development of an integrated, multimodal, and efficient transport infrastructure network;
- Implementation of measures to foster research and the development of new technologies in the sector;
- Introduction of regulations that promote sustainability and safety in transport.

With regard to urban mobility, Directive 2014/94/EU establishes the framework for sustainable urban mobility, with the primary goal of developing infrastructure that supports the use of alternative fuels to reduce oil dependency and greenhouse gas emissions. To this end, the Directive establishes the following measures:

- The installation of charging points for electric vehicles in urban and suburban areas;
- The development of refuelling stations for liquefied natural gas (LNG) and compressed natural gas (CNG) along transport corridors;
- The promotion of hydrogen use through the creation of a hydrogen refuelling network;

- Strengthening the connectivity of alternative fuel infrastructure across the EU.

The present section is intended to serve as an introduction to the study and thus comprises a presentation of the hypothesis (H1) to be tested. This is followed by a literature review of the transport policies in the countries under study, and in addition to a review of academic articles that apply DEA to the analysis of transport efficiency. The subsequent section delineates the methodology and the sample utilised. The paper then presents the results, followed by a final section discussing the findings and drawing conclusions.

1. Literature Review

1.1 European Transporter Policies

The European Green Deal (European Commission, 2020) sets out a roadmap aiming to make Europe the first climate-neutral continent by 2050, addressing multiple sectors, including transport. In addition to these major regulatory frameworks, presents further EU transport-related directives and regulations adopted in recent years are presented in *Table 1*.

Table 1. Other Relevant EU Regulations in the Field of Transport UE

Regulation	Objective
Regulation (EC) nº 1370/2007	To regulate public passenger transport services by rail and by road.
Directive 2012/34/EU	To establishe a single European railway area.
Regulation (EU) nº 181/2011	To define the rights of bus and coach passengers.
Regulation (EC) nº 1371/2007	On the rights and obligations of rail passengers.
Directive 2008/50/EC	To address air quality and urban zones.
Regulation (EU) 561/2006	To harmonise social legislation relating to road transport.
Regulation (EU) 2020/1056	To promote multimodal service provision, digitalisation, and technological innovation.

Source: own elaboration.

Subsequently, *Table 2* outlines the key aspects of public transport policies in the countries under study, and how they have implemented the EU regulatory framework.

The analysis of this regulatory framework highlights the considerable challenges faced by operating companies in terms of investment in fleet renewal and user information technologies, directly influencing their management practices and the efficiency with which public transport services are delivered.

Table 2. Comparative Overview of Key Aspects of Transport Policies: France, Italy, Germany, and Spain

Country	Urban Mobility	Sustainability	Financing
France	**Regulatory framework: Transport Code (2025)**		
	• Decentralised and managed by local mobility organising authorities. • Low Emission Zones (LEZ) implemented in various cities (Loi n° 2021-1104). • Urban Travel Plans (Plans de Déplacements Urbains - PDU) mandatory for municipalities with over 100,000 inhabitants (Loi n° 82-1153).	• Reform of the French Transport Code regarding emissions in the transport sector (Loi n° 2025-391). • Restrictions on the circulation of heavy-duty vehicles (Arrêté du 16 avril 2021).	• Strengthening of financing mechanisms and tax incentives, especially for low-emission vehicles (Loi n° 2025-391). • Support measures for local authorities on accesibility and sustainability (Loi n° 2025-391).
Italy	**Regulatory framework: Legislative Decree No. 422/1997 – transfers transport competences from the State to the regions**		
	• Competences are decentralised at the regional level. • LEZs under local authority control but supervised by the national authority. • Framework Law on Local Public Transport: regulates competences, organisation, financing, and service contracts (Decreto ministeriale 23 dicembre 2024, n. 335) • Sustainable Urban Mobility Plans (SUMP) mandatory for cities over 100,000 inhabitants (Decreto Ministeriale n. 397).	• National Strategic Plan for Sustainable Mobility: financing for the renewal of bus fleets with lower-emission technology.	• National Fund for the State's Financial Contribution to Local Public Transport Costs: the Italian State co-finances public transport (Decreto dirigenziale n. 127).
Germany	**Regulatory framework: Passenger Transport Act (2024) – regulates public road transport.**		
	• Decentralised: managed by local transport authorities. • LEZs (Umweltzonen) under local control, in line with federal emissions regulations. • Sustainable Urban Mobility Plans (SUMP) mandatory for cities with over 50,000 inhabitants (MobG).	• Climate Protection Programme 2030 (Klimaschutzprogram m): promotes improvements in public transport and reduction of private vehicle use.	• Municipal Transport Financing Act (GVFG): provides funding for infrastructure investments, fleet renewal with cleaner technologies, route expansion, etc.
Spain	**Regulatory framework: Law 16/1987 on the Organisation of Land Transport.**		
	• Decentralised at both regional and municipal levels. • LEZs under local jurisdiction for municipalities with over 50,000 inhabitants, or over 20,000 if air quality thresholds are exceeded (Ley de Cambio Climático y Transición energética 2021). • Sustainable Urban Mobility Plans (SUMP) mandatory for cities with more than 50,000 inhabitants (Ley de Cambio Climático y Transición energética 2021)	• Sustainable Mobility Law currently under legislative procedure. • No national regulation governs transport financing.	• No national regulation governs transport financing. • Funding provided jointly by the State and Autonomous Communities. • Regulated at the regional and/or municipal level.

Source: own elaboration.

1.2 DEA Models in Recent Studies

The definition of "efficiency" in the public transport sector has been the subject of debate since the 1980s (Tsai *et al.*, 2015). In recent years, there has been a considerable expansion in the academic literature on measuring and evaluating efficiency in this field, driven by two factors: the growing need to enhance transport performance and the increasing competition among service providers (Kráľ and Roháčová, 2013). According to Fitzová *et al.*

(2018), recent studies have contributed to the broader discussion on urban transport system efficiency and informed the design of more effective public policies in this area.

A plethora of methodologies have been developed to assess the efficiency of public transport, with Data Envelopment Analysis (DEA) emerging as one of the most widely adopted approaches (Tsai *et al.*, 2015). DEA is a non-parametric linear programming method that identifies the production frontier and computes inefficiency scores for each transport company in the sample (Tsai *et al.*, 2015). Numerous studies have explored efficiency measurement in public transport applying DEA models (Kráľ and Roháčová, 2013), thereby establishing DEA as a valuable and practical tool to support decision-making in the transport sector and beyond (Roháčová, 2015). Tsai *et al.* (2015) argue that DEA offers a flexible framework that allows for the inclusion of multiple indicators, which serve as input and output variables in the models used to quantify and assess the performance and efficiency of transport operators. In this context, *Table 3* presents a comparison of the indicators used in some of the most recent studies.

Kráľ and Roháčová (2013) compare the efficiency of road public transport companies, specifically bus and urban transport operators in Slovakia. Tsai *et al.* (2015), on the other hand, aim to assess cost efficiency across various international urban railway systems from Asia, Australia, Europe, and North America, identifying factors that drive operational performance and efficiency. Fitzová *et al.* (2018) go beyond the use of standard DEA inputs and outputs by incorporating a wide range of explanatory variables, such as economic, socio-economic, operational, political, and demographic, to identify key determinants of efficiency in the Czech public transport sector. Other studies focus on evaluating the technological efficiency of urban transport in selected Polish cities, assessing the relationship between the efficiency scores obtained and public expenditure on urban transport, as well as identifying areas for improvement (Hajduk, 2018). Roháčová (2015) also provides viable suggestions and recommendations for improving efficiency and optimising urban public transport systems in a Slovak city under study.

Regarding railway efficiency, Niu *et al.* (2023) conduct a comparative analysis of sixteen countries, focusing on general characteristics of the rail networks to allow for macro-level comparisons. Flores *et al.* (2024) examine the relationship between the efficiency of Spanish urban transport operators, their management models (public or private), and the size of the enterprises. Previous research (Díaz, Charles, 2016) had already focused on the effect of institutional characteristics, such as operator ownership and regulatory contract type, on the efficiency of urban transport companies in France. Sánchez Toledano *et al.* (2025) explore overall, energy, and environmental efficiency of urban transport firms, comparing bus and metro systems.

Table 3. Review of the DEA Models used in the Studies Analysed

Publication	Method	Sample	Period	Inputs	Outputs
Král' and Roháčová (2013)	DEA and Stochastic Frontier Analysis (SFA)	20 transportation companies of the Slovak Republic	2010	▪Average number of employees ▪Total kilometres driven ▪Total number of vehicles ▪Tangible fixed assets ▪Operation costs	▪Total number of passengers ▪Total sales
Roháčová (2015)	Special adjusted DEA model (Hybrid-DEA model)	28 Banská Bystrica's urban public transport lines (Slovak Republic)	2008 (week 41)	▪Number of stops ▪One-way transport distance ▪Daily number of connections ▪Average transport capacity of dispatched vehicles ▪Transport performance in kilometres driven ▪Operation costs of passenger transportation	▪Number of passengers/chip card ▪Number of passengers/ticket bought in cash ▪Total number of passengers ▪Total sales of passenger transportation
Tsai *et al.* (2015)	Two-stage DEA models (DEA and Tobit)	20 international urban rail systems in Asia, Australia, Europe and North America	2009–2011	Inputs: ▪Labour (total number of employees of the system operator) ▪Rolling stock (total number of cars in operation) Input prices: ▪Labour price ▪Capital price	▪Car-km ▪Patronage
Díaz and Charles (2016)	Conditional DEA frontier approach and semiparametric method	126 cities (metropolitan areas in France)	1995–2010	▪Total number of full-time employees in the year ▪Number of vehicles in the network ▪Fuel consumption	▪Number of seat-kilometers provided
Fitzová *et al.* (2018)	DEA VRS CRS model and Tobit regression	19 urban public transport systems in the Czech Republic	2010–2015	▪Number of full-time equivalent employees ▪Total number of vehicles (rolling stock) ▪Material and fuel costs (energy)	▪Number of passengers
Hajduk (2018)	DEA method and BCC model	18 Polish cities with district status from 150 to 500 thousands inhabitants	2015	▪Transport expenditures	▪Length of urban roads ▪Length of bus-lines ▪Length of bicycle paths
Niu *et al.* (2023)	Three-stage DEA model	Railway transport in 16 countries	2010–2018	▪Length of railway lines ▪Average number of staff members ▪Number of locomotives ▪Annual consumption of energy by railway transport ▪Ratio of non-electrified railway tracks to electrified railway tracks	▪Passengers-kilometres ▪Freight-tonnes-kilometres

Table 3 *(continuation).* Review of the DEA Models used in the Studies Analysed

Flores *et al.* (2024)	DEA, the Malmquist Index and inference estimators to determine productivity, efficiency change into Pure Technical Efficiency Change (PTECH) and scale efficiency change	229 public-private urban transport operators in Spain	2012–2021	▪Depreciation and amortization expenses as an indicator of rolling stock expenses ▪Employee cost to measure personnel resources ▪Procurement cost as a measure of energy consumption	▪Added value of the service (Depreciation and amortisation expenses + Procurement costs + Cost of employees)
Sánchez Toledano *et al.* (2025)	DEA method and Malmquist Index	8 bus mode and metro mode operators in Spain	2017–2022	▪Sum of personnel expenses ▪Depreciation ▪Energy cost as a measure of energy consumption	▪Number of travelers ▪Network kilometers
Current study	DEA (Model 1 General efficiency and Model 2 Simplified general efficiency) and Malmquist Productivity Index (MPI)	499 passenger transport companies in four different countries (Germany, Italy, Spain and France)	2015–2023	▪Material costs ▪Employee costs	▪Revenue ▪Ordinary income ▪ROA using earnings before tax

Source: own elaboration.

The present study analyses metro and bus transport companies operating in four European countries (Germany, Italy, Spain, and France), aiming to identify the best management practices and proposing strategies to enhance the performance and efficiency of operators. A distinctive contribution of this work lies in the comparative analysis over the study period of 2015–2023, which encompasses the years before, during, and after the global COVID-19 pandemic.

2. Methodology, Sample and Data

2.1 Methodology

In this study, efficiency is assessed using Data Envelopment Analysis (DEA), a linear programming technique originally developed by Charnes, Cooper, and Rhodes (1976), building upon the earlier work of Farrell (1957). The units of analysis, referred to as Decision Making Units (DMUs), are subway and bus transportation companies operating in Europe. The main objective is to identify optimal management practices by analysing the efficiency frontier and to determine suitable strategies for enhancing the performance of inefficient operators.

As outlined by Charnes, Cooper, and Rhodes (1976), the purpose of the linear programming model presented in equation (1) is to identify the optimal weights for inputs and outputs that define the production model, in such a way that the efficiency score of each Decision Making Unit (DMU) within the reference set is maximised. Let n be the number of DMUs in the sample; s, the number of input variables; and m, the number of output variables considered in the production model.

$$
\begin{aligned}
&maxE_j = \frac{\sum_r u_r y_{rj}}{\sum_i v_i x_{ij}} \\
&s.t.\begin{cases} 0 \le \dfrac{\sum_r u_r y_{rj}}{\sum_i v_i x_{ij}} \le 1 \ \ \forall j = 1, \dots, n \\ u_r, v_i \ge 0 \ \forall r = 1, \dots, m; i = 1, \dots, s \end{cases} \qquad Model\ (1)
\end{aligned}
$$

Where x_{ij} is the input variable *i* amount for DMU *j*, y_{rj} is the output variable *r* amount for DMU *j*, v_i is the weight value for input variable *i*, and u_r is the weight value for output *r*. The model specified in equation (1) corresponds to the Constant Returns to Scale (CRS) assumption, under which a proportional increase in input levels results in a proportional increase in output levels. To account for scale efficiency, this study also employs the extended model known as Variable Returns to Scale (VRS), introduced by Banker *et al.* (2006).

In order to ensure a homogeneous sample, this study employs a methodology for the identification of atypical data, specifically, decision-making units (DMUs) that exhibit extreme input or output values relative to the rest of the sample. Detecting outliers is particularly challenging in DEA, as each DMU is represented by a multidimensional vector of inputs and outputs. Outliers may arise due to various factors, such as unique characteristics not shared by other units in the sample (Chen *et al.*, 2010) or membership in a different reference group (Johnson and McGinnis, 2008). DEA results are especially sensitive to the presence of outliers, since the method relies on extreme observations to define the performance frontier (Sexton *et al.*, 1986). A range of techniques has been proposed in the literature for outlier detection (e.g., Banker and Chang, 2006; Bellini, 2012; Chen *et al.*, 2010; Johnson and McGinnis, 2008; Simar, 2003). In this study, the approach developed by Bellini (2012) is adopted, as it enables the detection of outliers both on and off the production frontier.

In order to determine the optimal number of outputs to be included in the model, factor analysis was employed as a dimensionality reduction technique. This method constructs *k* latent factors, where *k* is an integer between 1 and the total number of original variables, based on the correlation matrix. These factors are defined as linear combinations of the original variables, and capture the common variance shared among them. The resulting k-dimensional space enables the identification of linear relationships between the original variables and can assist in the revelation of redundant or irrelevant ones. To enhance interpretability, axis rotation was applied when necessary, allowing the factor structure to better align with the underlying data patterns. The overall and simplified models are compared to find possible statistical differences.

To assess the performance of the DMUs in the reference set over the years analysed in this study, the Malmquist Productivity Index (MPI), as developed by Färe and Grosskopf (1992), is employed. The index, presented in equation (2), represents the geometric mean of two Malmquist indices originally proposed by Caves *et al.* (1982), which correspond to the production technologies at time periods *t* and *t + 1*:

$$MI^{(t,t+1)} = \sqrt{\frac{D_i^t(y^{t+1},x^{t+1})D_i^{t+1}(y^{t+1},x^{t+1})}{D_i^t(y^t,x^t)D_i^{t+1}(y^t,x^t)}} \qquad (2)$$

where $MI^{(t,t+1)}$ is the input-oriented Malmquist index, *y* represents the output vector that can be produced using the input vector x and $D_i^{t_2}(y^{t_1},x^{t_1})$ shows the efficiency measure using observation at period t_1 relative to the frontier technology at period t_2. For a more detailed explanation of the methodology, see Coelli *et al.* (2005). In this study, the decomposition suggested by Grifell-Tatjé and Lovell (1995), with the aim to differentiate the origin of the changes in productivities

The Kruskall Wallis distribution equity is used to find possible differences between countries, as the efficiency scores distribution fails in the normality assumption. The H statistic obtained in the test is compared to a chi-squared distribution. To find possible differences between the years under study and the country, a mixed linear model was considered. The statistical analysis was performed with SPSS (IBM SPSS Statistics, version 24.0, IBM Corporation) and R programming language. P values of <0.005 were considered statistically significant, as per the recommendations in Benjamin *et al.* (2018).

2.2 Sample

The sample includes 499 passenger transport companies for the period between 2015 and 2023 in the four biggest countries in the EU by population and GDP (France, Germany, Italy, and Spain). The selection of the sample is justified by the existence of the transport mode under analysis in these countries, and the availability of their operational data. The data for this study have been obtained from the Orbis database, extracted with the NACE code 4931 "Urban, Suburban Land Passenger Transport". The inputs and outputs considered are based on the literature review conducted and the availability of common data for the enterprises analysed. *Table 4* presents the references considered for the selection of variables.

Table 4. Inputs and Outputs Considered in the Analysis

Inputs and Outputs	References[1]
Material cost millions USD	Fitzová *et al.* (2018)
Employee costs million USD	Flores *et al.* (2024), Sánchez-Toledano *et al.* (2025)
Revenue	Jarboui (2016)
Ordinary Income (OI)	Král' and Roháčová (2013), Roháčová (2015)
ROA using earnings before tax (ROA)	Silalahi *et al.* (2023)

Source: own elaboration.

After analysing the available data, the use of a total of 499 companies is ruled out because the available data is not consistent throughout the years of the series. *Table 5* represents the total number of companies included in the sample by country.

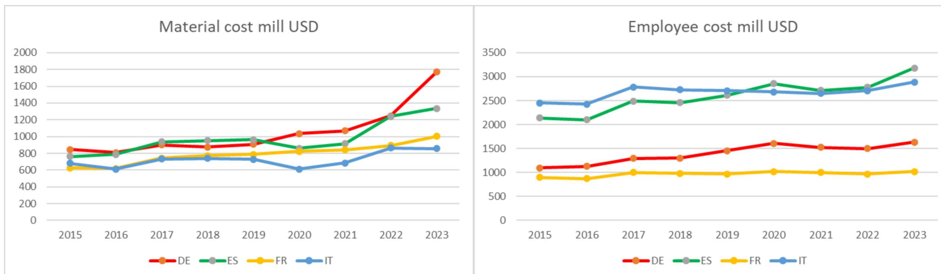
Table 5. Sample Description

Country	Number of companies available	Number of companies excluded from the sample	Number of companies included in the final sample	Total ordinary income (2023), in millions (USD)
France	73	0	73	2,169.38
Germany	27	3	24	5,380.74
Italy	209	15	194	6,666.41
Spain	237	29	208	6,242.85
TOTAL	**546**	**47**	**499**	**20,459.38**

Source: own elaboration.

[1] Jarboui (2016) applies Stochastic Frontier Analysis (SFA) to assess the efficiency of transport companies across 18 countries between 2000 and 2011. Silalahi et al. (2023) employ the normal distribution test and the paired T-test to measure efficiency in 45 transport companies listed on the Indonesia Stock Exchange. The remaining studies use DEA and have been discussed in the literature review.

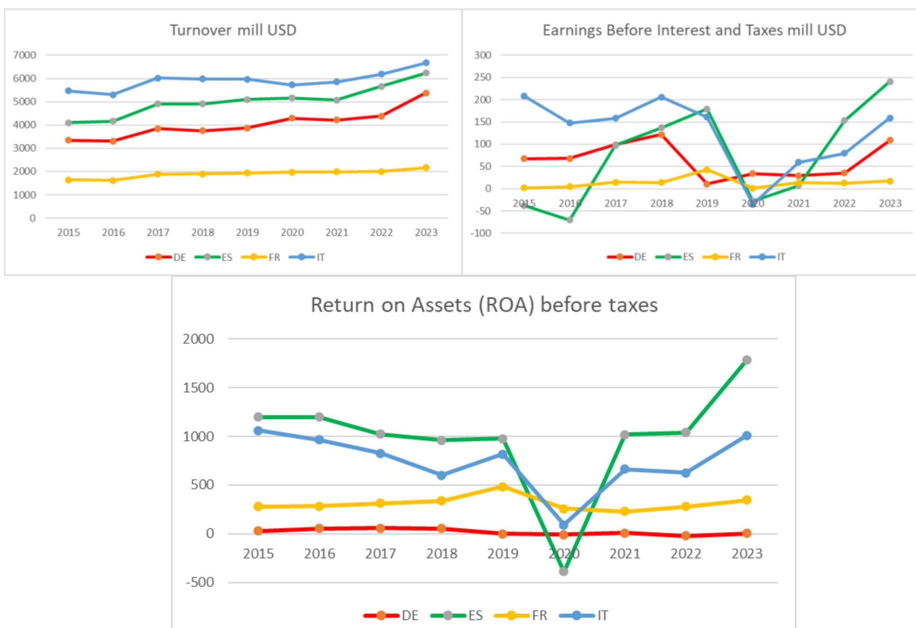
The evolution of inputs by country are depicted in *Figure 1*.



Source: own elaboration.

Figure 1. **Evolution of Inputs in the Analysed Companies by Country (2015–2023)**

The evolution of outputs by country can be seen in *Figure 2*. As expected, a notable decrease is experienced in 2020 due to the global pandemic caused by COVID-19.



Source: own elaboration.

Figure 2. **Evolution of Outputs in the Analysed Companies by Country (2015–2023)**

2.3 Variables

Factor analysis is employed to reveal redundant or irrelevant variables in the database from the three outputs considered in this study. The correlation matrix between the output variables is presented in *Table 6*, which shows that there are significant correlations among them in the period under consideration. In addition, ordinary income is correlated to revenue and ROA in all the years under consideration except in 2016 and 2016.

Table 6. Correlation Matrix between Outputs Considered in the Sample in the Period under Consideration

Correlation				
Year	**Variable**	**Revenue**	**Ordinary Income**	**ROA**
2023	Revenue	1	..289**	-.110*
	Ordinary Income	.289**	1	.218**
	ROA	-.110*	.218**	1
2022	Revenue	1	.289**	-0.074
	Ordinary Income	.289**	1	.366**
	ROA	-0.074	.366**	1
2021	Revenue	1	-.199**	-.094*
	Ordinary Income	-.199**	1	.286**
	ROA	-.094*	.286**	1
2020	Revenue	1	-.152**	0.004
	Ordinary Income	-.152**	1	.306**
	ROA	0.004	.306**	1
2019	Revenue	1	.068**	-.067
	Ordinary Income	.068**	1	.223**
	ROA	-.067	.223**	1
2018	Revenue	1	.535**	-0.056
	Ordinary Income	.535**	1	.223**
	ROA	-0.056	.223**	1
2017	Revenue	1	.361**	-0.075
	Ordinary Income	.361**	1	.245**
	ROA	-0.075	.245**	1
2016	Revenue	1	-0.075	-.112*
	Ordinary Income	-0.075	1	.184**
	ROA	-..112*	.184**	1
2015	Revenue	1	0.046	-.096*
	Ordinary Income	0.046	1	.174**
	ROA	-.096*	.174**	1

*. The correlation is significant at the level 0.05 (bilateral).
**. The correlation is significant at the level 0.01 (bilateral).

Source: own elaboration.

Bartlett's test of sphericity (Bartlett, 1937), presented in *Table 6*, is used to assess whether the correlation matrix of the variables under study significantly differs from an identity matrix, an indicator that the variables are interrelated and thus appropriate for structure detection. A high test statistic (with corresponding low p-value) suggests that it is unlikely the correlation matrix is an identity matrix, confirming the suitability of the data for factor analysis due to the presence of potential linear relationships among variables. In addition, the Kaiser-Meyer-Olkin (KMO) measure evaluates the proportion of variance among variables that may be attributed to underlying latent factors. Values closer to 1 indicate greater sampling adequacy and support the appropriateness of factor analysis. The adequacy of PCA for the data sample in the period under study can be observed.

It is concluded that the principal components analysis has an adequate sample (Kaiser, 1974) and that the identity proximity of the correlation matrix approximation hypothesis is rejected. It is observed that constructing two factors preserves in average the 79%±4.6% of the information in terms of the cumulative variance provided by the first two components (see *Table 7*). As expected, ordinary income and ROA can be considered as a unique factor (see

Table 7) in the majority of the years in the period under consideration; therefore, two outputs are finally considered in this study.

Table 7. PCA Statistics

Year	KMO and Bartlett			Eigenvalues			Component matrix		
				Component	Total	% Cum	Variable	Factor 1	Factor 2
	KMO		0.408	1	1.315	43.826	Revenue	**0.665**	-0.604
2023	Bartlett	χ2	84.864	2	1.105	80.668	OI	**0.861**	0.107
		Sig.	<.001	3	0.580	100	ROA	0.362	**0.854**
	KMO		0.409	1	1.432	47.720	Revenue	0.472	**0.816**
2022	Bartlett	χ2	135.368	2	1.073	83.477	OI	**0.878**	0.041
		Sig.	<.001	3	0.496	100	ROA	**0.662**	-0.636
	KMO		0.544	1	1.397	46.559	Revenue	-0.555	**0.795**
2021	Bartlett	χ2	63.208	2	0.912	76.974	OI	**0.779**	0.103
		Sig.	<.001	3	0.691	100	ROA	**0.694**	0.520
	KMO		0.483	1	1.340	44.656	Revenue	-0.359	**0.896**
2020	Bartlett	χ2	61.742	2	1.004	78.107	OI	**0.821**	-0.008
		Sig.	<.001	3	0.657	100	ROA	**0.733**	0.447
	KMO		0.469	1	1.223	40.764	Revenue	0.003	**0.954**
2019	Bartlett	χ2	31.140	2	1.035	75.273	OI	**0.782**	0.247
		Sig.	<.001	3	0.742	100	ROA	**0.781**	-0.252
	KMO		0.429	1	1.562	52.057	Revenue	**0.827**	-0.387
2018	Bartlett	χ2	215.895	2	1.040	86.714	OI	**0.896**	0.070
		Sig.	<.001	3	0.399	100	ROA	0.274	**0.941**
	KMO		0.418	1	1.403	46.780	Revenue	**0.702**	-0.570
2017	Bartlett	χ2	116.393	2	1.070	82.441	OI	**0.868**	0.069
		Sig.	<.001	3	0.527	100	ROA	0.396	**0.860**
	KMO		0.539	1	1.254	41.801	Revenue	-0.521	**0.839**
2016	Bartlett	χ2	24.984	2	0.935	72.965	OI	**0.679**	0.443
		Sig.	<.001	3	0.811	100	ROA	**0.722**	0.188
	KMO		0.467	1	1.182	39.408	Revenue	-0.243	**0.896**
2015	Bartlett	χ2	21.943	2	1.039	74.025	OI	**0.699**	0.466
		Sig.	<.001	3	0.779	100	ROA	**0.796**	-0.135

Note: *OI=ordinary income.

Source: own elaboration.

The combination of these outputs has generated the following models:
Model 1: General efficiency
Input: material and employee costs in millions USD.
Output: revenue, ordinary income (OI) and ROA using earnings before tax (ROA).
Model 2: Simplified general efficiency
Input: material and employee costs in millions USD.
Output: revenue and ROA using earnings before tax (ROA).

3. Results

3.1 Outlier Detection

In the period under consideration, 2% of the companies were identified as outliers. *Table 8* presents the DMUs identified as atypical data that exhibit extreme input or output values relative to the rest of the sample in at least seven of the years under consideration. 36 DMUS were identified at least once as atypical in the period under consideration.

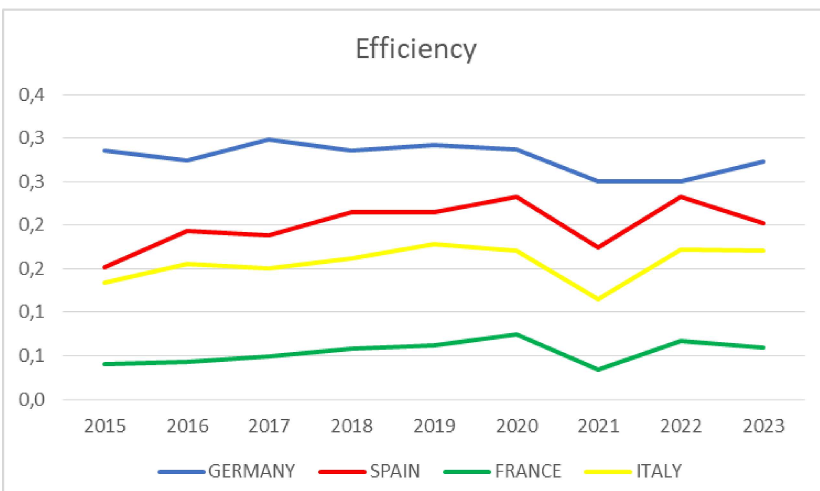
Table 8. Atypical DMUs and Number of Times Detected as Outlier

DMU	N	Country
AVANZA SPAIN SL	9	ES
COTRAL S.P.A.	9	IT
GRUPPO TORINESE TRASPORTI S.P.A. SIGLABILE GTT S.P.A.	9	IT
KEOLIS LYON	9	FR
STADTWERKE HAMM GESELLSCHAFT MIT BESCHRAENKTER HAFTUNG	9	DE
EMPRESA MUNICIPAL DE TRANSPORTES DE MADRID SA	8	ES
STADTWERKE MUENSTER GMBH	8	DE
TPER S.P.A.	8	IT
VESTISCHE STRASSENBAHNEN GESELLSCHAFT MIT BESCHRAENKTER HAFTUNG	8	DE
STADTWERKE NEUSS GMBH	6	DE

Source: own elaboration.

3.2 General Efficiency Model

With regards to the general efficiency model, *Figure 3* presents the efficiency for the DMUs in the reference set considering a VRS model input oriented in the time period under consideration by country.



Source: own elaboration.

Figure 3. **Efficiency for Each DMU in the Reference Set for the General Efficiency Model by Country**

The DEA model of the present study revealed that 8 of DMUs were efficient in the period under study (see *Table 9*). It is worth to mention that although efficient in the period under evaluation, BERLINER VERKEHRSBETRIEBE (BVG) and CONSORZIO TRASPORTI AZIENDE PUGLIESI IN SIGLA CO.TR.A.P were in the set of peers of a unique or none other DMUs, which indicates they are self-evaluators, being unable to emulate their management process by the rest of inefficient DMUs. This represents 1.6% of the companies in the sample. The average efficiency is maintained in the period under study being in 2015 ($\bar{E}_{2015} = 0.135$), 2016 ($\bar{E}_{2016} = 0.161$), 2017 ($\bar{E}_{2017} = 0.158$), 2018 ($\bar{E}_{2018} = 0.175$), 2019 ($\bar{E}_{2019} = 0.182$), 2020 ($\bar{E}_{2020} = 0.188$), 2021 ($\bar{E}_{2021} = 0.134$), 2022 ($\bar{E}_{2022} = 0.186$), and 2023 ($\bar{E}_{2023} = 0.173$).

Table 9. DMUs Identified as Efficient in the General Model

DMU	Country	Ownership
BERLINER VERKEHRSBETRIEBE (BVG)	DE	Public
CONSORZIO TRASPORTI AZIENDE PUGLIESI IN SIGLA CO.TR.A.P.	IT	Public
CONTRAM MOBILITA' SOCIETA' CONSORTILE PER AZIONI.	IT	Mixed
METRO DE MADRID SA	ES	Public
METRO DE MALAGA SA	ES	Mixed
ODEG OSTDEUTSCHE EISENBAHN GMBH	DE	Private
REGIONALBAHN KASSEL GMBH	DE	Private
STADTWERKE MUENSTER GMBH	DE	Public

Source: own elaboration.

Table 10. Summary of Changes in Malmquist Index, Technical Change and Efficiency Change

Period	Summary	Malmquist index	Technical change	Efficiency change	Pure efficiency	Scale efficiency
	Progress	237	99	368	368	0
	No change	0	0	17	17	499
2015/16	Decline	260	398	114	114	0
	Mean	1.017	0.826	1.289	1.289	1
	Progress	369	370	5	107	112
	No change	16	16	488	0	1
2016/17	Decline	110	109	2	386	380
	Mean	3.293	3.293	3.005	2.947	2.963
	Progress	372	373	9	106	112
	No change	16	16	484	0	2
2017/18	Decline	107	106	2	387	379
	Mean	4.292	4.292	4.003	3.943	3.951
	Progress	373	374	13	106	116
	No change	16	16	480	0	2
2018/19	Decline	106	105	2	387	375
	Mean	5.292	5.292	5.003	4.943	4.952
	Progress	373	374	17	105	118
	No change	16	16	476	0	2
2019/20	Decline	106	105	2	388	373
	Mean	6.294	6.294	6.005	5.944	5.953
	Progress	376	377	21	107	121
	No change	16	16	472	0	2
2020/21	Decline	103	102	2	386	370
	Mean	7.299	7.299	7.009	6.948	6.958
	Progress	379	380	25	107	123
	No change	16	16	468	0	2
2021/22	Decline	100	99	2	386	368
	Mean	8.307	8.307	8.015	7.954	7.964
	Progress	380	381	29	106	123
	No change	15	15	464	0	2
2022/23	Decline	100	99	2	387	368
	Mean	9.315	9.315	9.023	8.961	8.971
	Progress	178	109	339	339	0
	No change	0	0	10	10	499
2015/23	Decline	311	380	150	150	0
	Mean	1.143	0.787	2	2	1

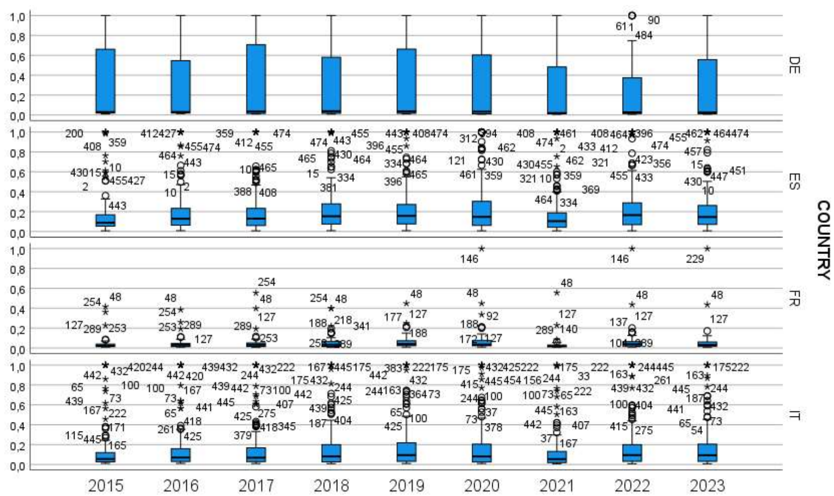
Notes: Obs. (EFCH) efficiency change, (TECH) technical change, (PEFCH) pure efficiency change, (SEFCH) scale efficiency change, and (MPI) Malmquist productivity index.

Source: own elaboration.

Table 10 shows changes in productivity, technology, efficiency, pure efficiency, and scale efficiency for the entire 2015–2023 sample period. The table illustrates the gradual increase in productivity from 2015 to 2023 attributed mostly to technical productivity "best practices". The decrease in productivity of 260 companies in 2015/2016 period and one-third of companies in the subsequent periods can be observed. Pure and scale efficiency experience a moderate fluctuation compared to technical efficiency.

3.3 Simplified Efficiency Model

In order to find possible differences between countries and the time period under study, a fixed model was used. No significant differences were found regarding the year although a general drop is observed in 2021 for all countries. However, significant differences were found by country in the general efficiency model (p-value≈0, F-statistic =52,92). *Figure 4* depicts the boxplot for each model with respect the efficiency scores by country. It can be observed that French companies present lower efficiency scores compared to the remaining countries, whereas Italian and Spanish companies present similar results.

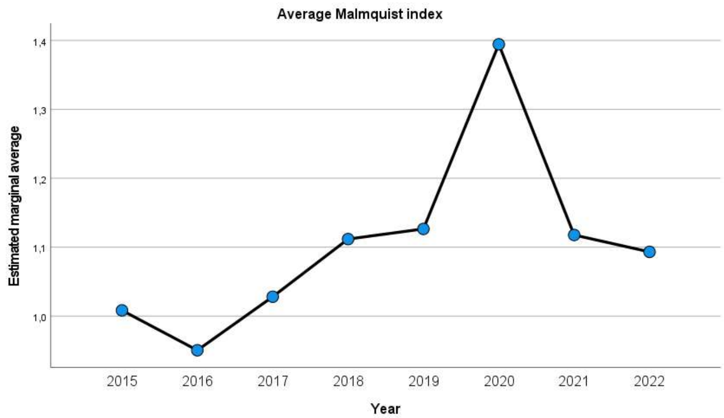


Source: own elaboration.

Figure 4. **Boxplot per Country of the Efficiency Scores**

Based on the results illustrated in *Figure 4*, Germany presents higher variance in efficiency with respect to the remaining three countries in the sample period. However, French companies present an average productivity maintenance in the sample period under study.

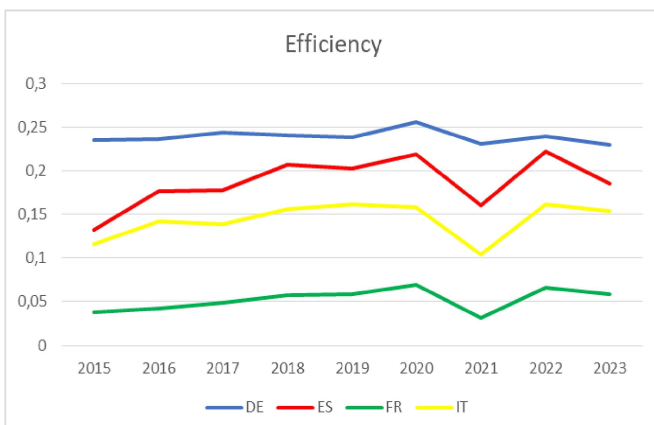
A fixed model was used to find possible differences between countries and the time period under study, with regards to the Malmquist Index. No significant differences were found regarding the country, although France presented the smallest average score ($\bar{M}_{\mathbf{France}} = 1.02$) in the sample period, as compared to the other three countries, i.e. $\bar{M}_{\mathbf{Germany}} = 1.16, \bar{M}_{\mathbf{Spain}} = 1.14,$ and $\bar{M}_{\mathbf{Italy}} = 1.14$, but significant differences were found by year in the general efficiency model (p-value≈0, F-statistic =4.71). *Figure 5* presents the average per year with respect to the Malmquist indices. The increase in the Malmquist Index in 2020 is observed.



Source: own elaboration.

Figure 5. **Average Malmquist Index per Year for the General Model**

Regarding the simplified efficiency model, *Figure 6* presents the efficiency for the DMUs in the reference set considering a VRS model input oriented in the time period under consideration by country.



Source: own elaboration.

Figure 6. **Efficiency for Each DMU in the Reference Set for the Simplified Efficiency Model by Country**

The DEA model in our study revealed that 6 of the DMUs were efficient in the period under study (see *Table 11*). It is worth to mention that, although efficient in the period under evaluation, BERLINER VERKEHRSBETRIEBE (BVG) was in the set of peers of a unique or none other DMUs, which indicates it is a self-evaluator, being unable to emulate their management process by the rest of inefficient DMUs. This represents 1.2% of the companies in the sample. The average efficiency is maintained in the period under study being in

2015 ($\bar{E}_{2015} = 0.117$), 2016 ($\bar{E}_{2016} = 0.146$), 2017 ($\bar{E}_{2017} = 0.147$), 2018 ($\bar{E}_{2018} = 0.167$), 2019 ($\bar{E}_{2019} = 0.167$), 2020 ($\bar{E}_{2020} = 0.175$), 2021 ($\bar{E}_{2021} = 0.123$), 2022 ($\bar{E}_{2022} = 0.177$), and 2023 ($\bar{E}_{2023} = 0.157$).

Table 11. DMUs Identified as Efficient in the Simplified Model

DMU	Country	Ownership
BERLINER VERKEHRSBETRIEBE (BVG)	DE	Public
CONSORZIO TRASPORTI AZIENDE PUGLIESI IN SIGLA CO.TR. A.P.	IT	Public
CONTRAM MOBILITA' SOCIETA' CONSORTILE PER AZIONI.	IT	Mixed
METRO DE MADRID SA	ES	Public
ODEG OSTDEUTSCHE EISENBAHN GMBH	DE	Private
STADTWERKE MUENSTER GMBH	DE	Public

Source: own elaboration.

Table 12. Summary of Changes in Malmquist Index, Technical Change and Efficiency Change for Simplified Model

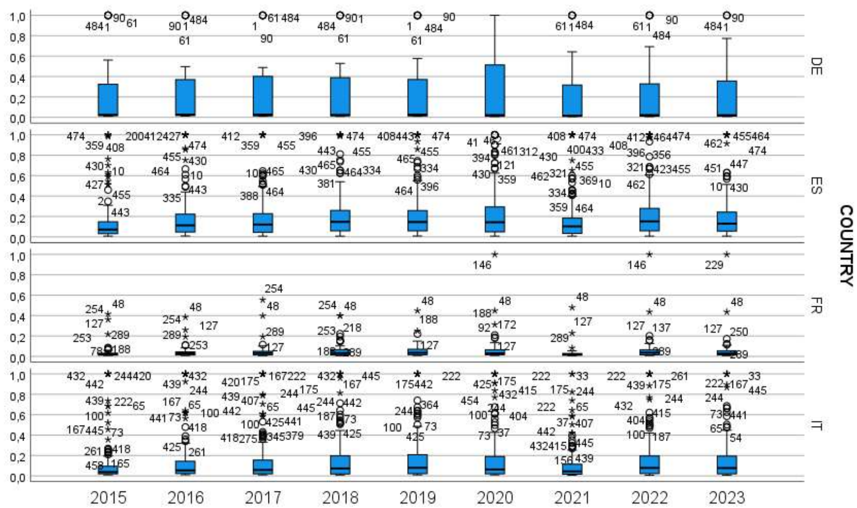
Period	Summary	Malmquist index	Technical change	Efficiency change	Pure efficiency	Scale efficiency
	Progress	271	50	438	438	0
	No change	0	0	15	15	499
2015/16	Decline	226	447	46	46	0
	Mean	0.996	0.720	1.504	1.504	1
	Progress	75	106	306	306	0
	No change	0	0	19	19	499
2016/17	Decline	422	391	174	174	0
	Mean	0.893	0.869	1.059	1.059	1
	Progress	258	394	126	126	0
	No change	0	0	18	18	499
2017/18	Decline	239	103	355	355	0
	Mean	1.009	1.103	0.929	0.929	1
	Progress	252	60	370	370	0
	No change	0	0	16	16	499
2018/19	Decline	244	436	113	113	0
	Mean	0.990	0.926	1.074	1.074	1
	Progress	360	484	73	73	0
	No change	0	0	12	12	499
2019/20	Decline	138	14	414	414	0
	Mean	1.319	1.700	0.804	0.804	1
	Progress	187	169	266	266	0
	No change	0	0	10	10	499
2020/21	Decline	309	327	223	223	0
	Mean	0.962	0.963	1.068	1.068	1
	Progress	147	23	421	421	0
	No change	0	0	9	9	499
2021/22	Decline	351	475	69	69	0
	Mean	1.067	0.686	1.528	1.528	1
	Progress	100	140	154	154	0
	No change	0	0	14	14	499
2022/23	Decline	396	356	331	331	0
	Mean	0.926	1.031	1.076	1.076	1
	Progress	152	101	347	347	0
	No change	0	0	7	7	499
2015/23	Decline	339	390	145	145	0
	Mean	1.008	0.726	2	2	1

Notes: Obs. (EFCH) efficiency change, (TECH) technical change, (PEFCH) pure efficiency change, (SEFCH) scale efficiency change, and (MPI) Malmquist productivity index.

Source: own elaboration.

Regarding the simplified model, *Table 12* illustrates changes in productivity, technology, efficiency, pure efficiency, and scale efficiency for the entire 2015–2023 sample period. The table indicates the maintenance in productivity from 2015 to 2023, except for in 2021/2022 where an increase is observed, attributed mostly to pure productivity best practices.

A fixed model was used to find possible differences between countries and the time period under study. Significant differences were found regarding the year (p-value≈0, F-statistic =3.31) and by country (p-value≈0, F-statistic =75.67) in the simplified efficiency model. *Figure 7* presents the boxplot for each model with respect the efficiency scores by country. It can be observed that French companies present lower efficiency scores compared to the remaining countries, whereas Italian and Spanish companies present similar results.

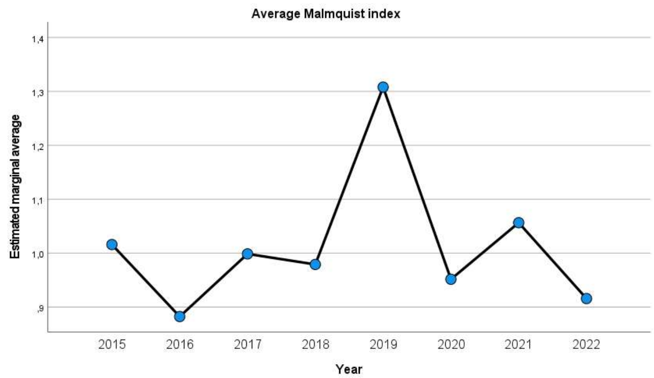


Source: own elaboration.

Figure 7. **Boxplot per Country of the Efficiency Scores**

Germany presents higher variance in efficiency in the sample period, as compared to the remaining countries. On the other hand, French companies present an average productivity maintenance in the sample period under study.

To find possible differences between countries and the time period under study respect the Malmquist index, a fixed model was used. No significant differences were found from the country perspective, although France presented the smallest average score ($\overline{M}_{\text{France}} = 0.981$) in the sample period, as compared to the other three countries under study ($\overline{M}_{\text{Germany}} = 1.005, \overline{M}_{\text{Spain}} = 1.02, \overline{M}_{\text{Italy}} = 1.04$). However, significant differences were found by year in the simplified efficiency model (p-value≈0, F-statistic =9.703). *Figure 8* presents the average per year with respect to the Malmquist Index. The increase in the Malmquist score in 2019 is observable.



Source: own elaboration.

Figure 8. **Average Malmquist Index per Year for the Simplified Model**

4. Implications and Discussion

Urban public transport is a key sector for cities from economic, social, and environmental perspectives, as it ensures citizens' accessibility with a lower environmental impact compared to other modes of transport. In this context, improving efficiency within companies operating in this sector should be a common objective, pursued both by corporate management and by policymakers and society at large.

This study provides empirical evidence on the comparative efficiency of the sector under analysis in the four largest countries of the European Union (Germany, France, Italy, and Spain) through the application of input-oriented Data Envelopment Analysis (DEA). The selected inputs and outputs are based on data availability and are widely accepted in previous international efficiency studies.

The results obtained reveal consistent and systematic differences in efficiency levels across the countries analysed, indicating the presence of structural and managerial disparities that significantly affect the relative performance of the entities and countries evaluated. Accordingly, the proposed hypothesis is accepted. Specifically, Germany and Spain exhibit higher average efficiency levels than Italy and France over the study period. The variation in efficiency among the companies analysed is particularly low in the case of French companies, whereas German companies show much wider dispersion.

The relatively low efficiency achieved by the vast majority of companies in comparison to the optimal frontiers identified poses significant implications for both managers and public policymakers. These national differences may not solely stem from internal management practices but could also be associated with exogenous variables such as the regulatory environment, funding policies, and the characteristics of each country's labour market.

Furthermore, while the impact of COVID-19 on the temporal evolution of the indicators used is evident, the overall efficiency trend remains stable, with a marked low point in 2021, the first post-pandemic year, and a pattern of evolution showing strong similarities across countries. The cases of Spain and Italy are particularly noteworthy due to their remarkably similar year-on-year variations.

As a recommendation for policymakers, the first point to highlight is the existence of clear examples of success. The analysis demonstrates that there are benchmark companies that enable cross-sector comparability, as reflected in *Table 13*, once the self-evaluators identified in the results section have been excluded, as these entities possess structures that are difficult to replicate.

Table 13. Benchmark Efficient Companies for Sector Comparability

Enterprise	Country	Ownership
CONTRAM MOBILITA' SOCIETA' CONSORTILE PER AZIONI.	IT	Public
METRO DE MADRID SA	ES	Public
METRO DE MALAGA SA	ES	Public
ODEG OSTDEUTSCHE EISENBAHN GMBH	DE	Private
REGIONALBAHN KASSEL GMBH	DE	Private
STADTWERKE MUENSTER GMBH	DE	Public

Source: own elaboration.

Regarding national policies, this study demonstrates that significant differences exist between countries, with Germany clearly emerging as the benchmark within the European Union. On the other hand, Spain and Italy show a positive temporal evolution over the period 2015–2023. France, however, is the major EU country with the greatest potential for improvement. Nevertheless, the sector as a whole requires a profound technological transformation to achieve the performance levels attained by large operators with substantial investment capacity, such as Berliner Verkehrsbetriebe (BVG) or Metro de Madrid S.A., as well as smaller companies that have strongly prioritised technological advancement, such as Contram Mobilità Società Consortile per Azioni or Metro de Málaga S.A. This is evident across both bus and rail modes.

In addition, with regard to the role of public ownership in urban transport, it is noteworthy that, of the total of eight companies identified as efficient according to the general model, 75% are publicly owned or have mixed ownership structures. In the case of the simplified model, of the six companies consistently efficient throughout the entire sample period, 83% are publicly owned or are mixed ownership entities.

From a scientific perspective, this study contributes to the advancement of knowledge in the field of efficiency measurement in international contexts by providing a rigorous comparison between economies of similar macroeconomic relevance within the European Union. It establishes comparable benchmarks that can inform future research and decision-making at both the sectoral and governmental levels, while highlighting the substantial potential for efficiency improvements within the sector.

Conclusions

It can be stated that the efficiency within the urban public transport sector is structurally different across the EU countries, primarily due to existing disparities in technological development and transport policies. In addition, factors such as ownership structure, company size, and transport mode do not appear to be decisive in achieving higher levels of efficiency.

Nevertheless, this study presents certain limitations that must be acknowledged. Firstly, the availability of homogeneous and comparable data across countries has constrained the selection of variables, necessitating the use of proxies which, although consistent with existing literature, may introduce a degree of measurement bias. Secondly, while the DEA methodology is robust for the analysis of relative efficiency, it does not directly account for the impact of external or contextual variables that may significantly influence the observed results. Future research could benefit from the application of Stochastic Frontier Analysis (SFA) approaches, which would allow for the control of environmental factors and enhance the robustness of the conclusions. The scope of this study could also be expanded by incorporating other EU member states or countries with similar macroeconomic characteristics, as well as by including new explanatory variables in the analysis.

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VIEŠOJO TRANSPORTO POLITIKA IR VEIKLĄ VYKDANČIŲ ĮMONIŲ EFEKTYVUMAS: EUROPOS ŠALIŲ PALYGINIMAS

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SANTRAUKA

Tvaraus judumo užtikrinimas yra vienas didžiausių šiuolaikinio viešojo valdymo iššūkių. Vyriausybės privalo taikyti politiką, kuri skatintų pažangą tvaraus, prieinamo ir efektyvaus judumo srityje. Todėl šio tyrimo tikslas – analizuoti transporto politikos poveikį ES šalių miesto ir priemiesčio transporto įmonių efektyvumui. Taikoma metodika apima šių įmonių pagrindinių kintamųjų aprašymą, duomenų apibendrinimo analizę ir Malmquist indeksą. Siekta pateikti statistinius produktyvumo, efektyvumo pokyčio (EFCH) į grynąjį techninį efektyvumo pokytį (PTECH) ir masto efektyvumo pokyčio įverčius, atlikta regresijos analizė, efektyvumą siejanti su transporto politika ES valstybėse narėse. Šis tyrimas papildo akademinę literatūrą ir leidžia pateikti teorines ir praktines rekomendacijas įvairiems transporto sektoriaus valdymo suinteresuotiesiems subjektams.

REIKŠMINIAI ŽODŽIAI: viešasis transportas; efektyvumas; transporto politika; tvarumas; duomenų apimties analizė; Europos Sąjunga.