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Measuring the Technical Efficiency of the Tunisian Collective Passenger Transport Companies Using Two-Stage DEA Model

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ABSTRACT: The aim of this study is to assess the level of technical efficiency and scale of Tunisian VCT companies, to determine the endogenous and exogenous factors that may explain their inefficiency and to analyze their economic implications on the performance of the sector.
Our approach is based on a two-stage DEA model. In the first stage, we used the classical DEA model in its two versions CRS and VRS under input orientation, to calculate the technical efficiency and scale score of each company throughout the study period.
In the second step, these efficiency scores will be regressed on non-discretionary variables using a Tobit model.
These models were applied to a sample of 117 observations consisting of panel data on the 13 public passenger transit companies covering the single urban network, over a period of 9 years from 2009 to 2017.
The results show considerable levels of total technical inefficiency in several companies. Only three firms are considered efficient. They reveal opportunities for improvement by decreasing the number of staff, the average age of buses, the occupancy rate and by adjusting the size and configuration of the network. The pure technical efficiency scores are higher and consistent. It indicates that the TCV industry has an increasing returns to scale, as well the existence of a mismatch problem between the company size and the managed traffic. Hence the need to merge small-sized business to achieve minimum efficiency.
Furthermore, this inefficiency can be explained by other exogenous factors that characterize the technical, demographic and economic environment in which the companies operate. This efficiency is all the higher as the population served is dense, the road network is well maintained, the motorization rate is low, the lines are of short or medium distances and the share of students is low.

KEYWORDS: technical efficiency, non-parametric DEA method, collective passenger transport, Tunisian public transport system, hydonic output, Tobit regression.
JEL classification : C14 ; D24 ; L91.

INTRODUCTION

The evaluation of efficiency in the collective passenger transport sector has been the subject of several recent scientific publications while using a variety of methods for measuring and estimating efficiency scores. These studies seek to detect the main factors explaining performance gaps between collective passenger transport companies (CPT) and to orient the decisions of these companies and of the public authorities concerned towards best practices aimed at improving the efficiency of failing companies, and to strengthen the role of CPT in the implementation of a sustainable development strategy.
Transport experts have shown that the CPT by bus or metro or tram is the most sustainable way to minimize the negative externalities of private transport by private car and to achieve cost saving both in terms of fuel consumption as well as congestion, as the emission of CO_2 (Berechman, 1993).
However, in most countries over the world, this sector suffers from many financial and structural problems which threaten its efficiency and limit its opportunities for expansion and improvement. They reduced its attractiveness, destroyed its brand image as well the loss of its market share in favor of the private car (De Borger et al, 2002).
Therefore, a special attention must be given to this sector in order to better strengthen its efficiency and competitiveness, maintain its position on the market and to provide a public service essential to the mobility and urban accessibility of citizens.

To achieve these objectives, it is first necessary to detect the different sources of the failure and identify the best operating practices in the public transport.

The efficiency study of this sector is thus necessary to provide the decision-makers with a dashboard for rational decision-making in terms of both resources allocation, network configuration and governance of CPT companies.

Economically speaking, this efficiency reflects the company's ability to fully use its inputs to produce the maximum of output at the lowest cost, or also to provide a certain level of output while minimizing its inputs (Atkinson and Cornwell, 1994).

Several approaches and models have been developed and exploited to evaluate the efficiency, whose most used are the parametric approaches exploiting the SFA method (Stochastic Frontier Analysis) and the nonparametric approach using the DEA method (Data Envelopment Analysis). These approaches seek to determine the production (or cost) efficiency frontier either through an econometric regression of a functional relationship between outputs and inputs or a linear programming of these variables.

The production frontier traces the maximum level of production that a firm can produce using the best technical production combinations. It reflects rational production behavior that seeks to avoid waste and to ensure best practices in the use of resources. A firm is efficient if it is on that production frontier.

In this sense, the efficiency measurement is based on a benchmarking between the firm's position and its production frontier. The efficiency score of a firm is calculated according to the difference between the level of the production achieved and that corresponding to the production efficiency frontier.

The application of these two parametric and non-parametric approaches to the public passenger transport sector has been the subject of several studies. However, the results obtained remain strongly influenced by the type of the used approach and model and the choice of the retained output and input variables (Kerstens, 1996). For the same sample of CPT firms, the studies developed yielded different results.

This nuance of the results lies particularly in the complexity of the transport industry's production and the multiplication of internal and external factors which can influence the level of efficiency. Several explanatory factors have been identified and analyzed, whether relating to the technical production process of the company studied or to its economic, institutional and demographic environment, which can influence both its demand and its production conditions.

In addition, several output indicators were used to assess the level of production of these transport companies without having any consensus. In fact, the CPT Company is a multi-product, networked industry, producing services of variable quality which are distinguished either by the line, the configuration of the network, the operated mode, the commercial speed, etc. It offers physical quantities of transport and distance units but also qualities evaluated by time, frequency, availability, accessibility, etc. This variability in output makes any aggregation of production in a single criterion inadequate with the industrial reality of the sector.

Transport output must reflect the heterogeneous nature of the transport service, rather than its network nature. Some authors have proposed the solution to disaggregate this measure by integrating in to a hedonic output the network characteristics and the quality of the transport service in order to heterogenize the supply of the transport company (Jara Diaz, 1982; Spady and Freidlander, 1978).

In addition, most studies have focused on the allocative sources of inefficiency while ignoring those relating to the business environment. Some studies (Boame, 2004; Margari et al, 2007; Sampaio et al, 2008; García Sánchez, 2009; Zhu et al, 2016, etc.) have clearly shown the great contribution of structural, transactional, economic, geographic and institutional factors , in explaining the differences in efficiency between companies.

These factors are generally outside the scope of the company that it cannot influence, but it undergoes the consequences of their changes. They can affect both the company's market potential and its supply conditions.

In fact, the company is not an autonomous entity where its efficiency depends only on the technical mechanisms of its production. It belongs to a politico-economic environment which influences its decisions and contributes in one way or another to determining its effectiveness (Margari et al, 2007).

In this article, based on this hedonic measurement of output transport and the two stages of the non-parametric DEA approach, we shall first measure the efficiency score of 13 Tunisian companies of CPT, all throughout the period 2009-2017. Then, we shall make a simple econometric regression taking as endogenous variable the efficiency score calculated by the DEA method and the explanatory variables, the indicators describing the environment surrounding the company. This regression known as the Tobit regression is particularly relevant when the endogenous variable is bounded between zero and one (Tobin, 1958).

This study will be articulated as follows: in a first section, we will proceed to a review of the literature dealing with this subject. Second, we turn to detail the DEA method which is the subject of our study. Then, we will state the empirical part of the work which consists first to measure the technical efficiency of the bus CPT system in Tunisia, on the other hand to analyze the estimation results and to explain the efficiency differences between the companies in our sample via a Tobit regression. Finally, we will end this article with a conclusion.

Several studies have been conducted to analyze the efficiency of public passenger transport services, particularly using non-parametric methods.

The very first studies limited their analyzes to measure the technical and scale efficiency scores, accusing ineffectiveness only of allocative and scale sources. These studies used different forms of data (temporal or cross-sectional or panel data) by combining conventional inputs (capital, labor and energy) to transform them into a generally single output evaluated from a supply perspective, measured by the number of seat kilometers or bus-kilometers offered. From demand perspective, it is measured by income or the number of passenger-kilometers transported (Chu et al, 1992; Nolan, 1996; Kerstens, 1996; Viton, 1997; Karlaftis, 2004, etc.).

The recent trend in this work is to analyze the impact of the economic, institutional, geographic, etc. environment, where the company reigns, over its performance. The main aim of these studies is to identify the main explanatory factors for the efficiency gap recorded between firms and to examine how these factors affect efficiency results. According to several studies, this external environment to the company positively and / or negatively affects the performance of the sector and largely explains the differences in efficiency between companies (Boame, 2004; Margari et al, 2007; Sampaio et al , 2008; García Sánchez, 2009; Zhu et al, 2016, etc.)

1. Literature Review

These studies used developed forms of the non-parametric DEA approach to integrate these environmental variables and test their effects on the efficiency of CPT companies. Among these forms are the two-stage DEA and the three-stage DEA, etc. Where Tobit regression has been widely applied to the efficiency scores calculated by the DEA method.

These studies differ in terms of their study sample, the output and input variables of CPT companies, the performance criteria used and the data analysis methodology. Kerstens (1996) demonstrated that the results on efficiency measuring of public transport systems differ considerably depending on the estimation methodology and outputs specification used.

Boame (2004) analyzed the technical efficiency of 30 urban transit companies in Canada, over the period (1990 - 1998) using the two-stage DEA Bootstrap method. In the first step, he calculated the efficiency score of all these decision units by combining 3 inputs (number of buses, fuel consumption and total hours worked) with a single output evaluated as revenue per vehicle - kilometers. The results show that the average efficiency of Canadian transportation systems is around 78% and that 56% of transit systems show increasing returns to scale.

In the second step, these calculated efficiency scores were regressed by a Tobit model based on a number of factors that may influence efficiency other than inputs. Four explanatory variables were retained in the model, such as average speed, average age of the fleet, peak traffic share and a time trend. It showed that average speed and time trend negatively affect efficiency while peak traffic share and the average age of the fleet negatively affect it.

In the Italian context, Margari et al. (2007) studied the impact of contract type on operator performance by adopting the three-step DEA method to overcome the deterministic gap in the DEA method. Applied on 42 Italian CPT companies between 1983 and 1999, this model combined a supply-oriented output measured by the number of seat-kilometers offered and four input variables (number of drivers, number of sedentary staff, amount of fuel consumed and cost of materials), to calculate and compare the efficiency scores between the companies studied. The authors concluded that the level of efficiency of these companies is both high and comparable and that companies providing urban traffic are more efficient than those specializing in interurban transport. In addition, the study tested three exogenous sources of efficiency such as regulatory practices measured by a dummy variable which takes 1 if the contract is at a fixed price and 0 otherwise, the technical operating conditions expressed by average commercial speed and average age of the fleet, potential demand represented by population density and technical progress illustrated by the time trend.

Finally, they re-executed the DEA process on the quantities of inputs purged of both exogenous effects and statistical noise. They found that the establishment of a governance regime based on a fixed price contract improves the efficiency score and reduces waste in the use of resources.

In order to highlight the characteristics of an efficient CPT system, Sampaio et al (2008) used the DEA method to compare the technical efficiency levels of 19 CPT companies 12 of which were European and 7 Brazilian. They used 3 input variables such as labor, capital evaluated by the number of vehicles and fuel and a single output variable evaluated by the number of passengers transported. They showed that only one Brazilian company and nine European companies are efficient. Subsequently, these efficiency scores were analyzed according to the governance modality and the pricing structure adopted by each company. They explained efficiency both through a process of partnership and equal sharing of decision-making power between governments, user associations and local communities, and through the application of a flexible pricing structure offering users several types of tickets that meet the interests of passengers.

Odeck (2008) tried to test the impact of CPT companies' mergers on both their efficiency score and their total factor productivity using the DEA method and the Malmquist productivity index. His study covered 17 passenger transport systems in Norway during the period 1995-2002. The study period was broken down into two phases, before and after merger. He used a single output variable evaluated in Seats-Kilometers offered and 3 input variables such as capital, labor and energy. The results show a potential for improvement in the efficiency and productivity of companies regardless of the analysis phase (pre or post-merger). Similarly, merger operations have improved this efficiency.

García Sánchez (2009) carried out an analysis of the efficiency of public bus transport in Spain using data envelopment analysis. He tried to compare the efficiency of 24 public transport systems according to 4 output conceptions defined respectively from a demand perspective, a supply perspective, a service quality perspective and a combinatorial perspective by aggregating the first three dimensions using the principal component analysis method to obtain a more global output indicator. The results obtained showed that the average levels of pure technical efficiency and scale are respectively 94.91 and 52.02%, that most of the technical inefficiency is in the form of scale inefficiency and that these results differ according to the optics used to identify output.

Furthermore, to identify the elements of heterogeneity in the environment in which the firms studied reign, he applied a Tobit regression. Seven environmental variables were selected such as population density, rent per capita, number of private vehicles, commercial speed, length of the bus network, a dummy variable illustrating the existence or not of other transport alternatives and a ratio indicating the share of peak hours. He noted that all of these variables had a negative effect on technical efficiency, except the number of private vehicles variable, whose effect was marginal and insignificant. It also found that the ownership system of the CPT company (public or private) had no effect on the efficiency score.

Hirschhausen and Cullmann (2010) analyzed the technical efficiency of 179 CPT companies in Germany over the period 1990-2004, using the DEA and Boostrapping methods to test the robustness of the estimates. They showed that the average technical efficiency of German bus companies is relatively low and that the efficiency score increases with the size of the firm. Small firms are less efficient than larger ones and have increasing returns to scale indicating that they can increase their size through the merger process.

In addition, these authors have tried to analyze the contribution of exogenous variables on efficiency. They chose a single variable such as population density defined by the number of inhabitants per kilometer of network of each transport company. This variable was included as an input in the DEA model affects the efficiency score positively and significantly. They deduced that transport operators in populated areas are more efficient than those serving low population density areas.

Zhu et al (2016) applied a three-step DEA model on a cross-sectional database of 39 bus lines operated by Jiangyin public company (China), to analyze the operational and services quality efficiency on each line. By combining 3 inputs (number of drivers, fuel and number of buses) and 4 output (two physical: revenue and number of bus-km and two qualitative: speed and average punctuality rate), they calculated in the first step the efficiency scores, by distinguishing between those relating to bus operation and those relating to quality. The second step aims to estimate these efficiency scores calculated via a stochastic model (SFA) as a function of four exogenous explanatory factors (route length, bus stops density, commercial speed and average stop time at stations).

Step 3 consists of repeating step 1 using inputs adjusted to obtain operational efficiency scores purged of environment and statistical nuisance effects.

They have shown that exogenous factors have an important and significant influence on the operating efficiency of bus lines, but they affect operational and quality efficiency differently. They confirmed that traffic congestion and the lack of priority measures for buses, put CPT system in good working order and that route length and average bus stop density are useful for operational efficiency, but not for quality efficiency.

2. Non-parametric model presentation: Data Envelopment Analysis

Thanks to Farrel (1957) that the concept of efficiency has been developed and systematized so that it can be calculated and tested in empirical studies. He proposed calculating the firm efficiency score according to the distance between the realized production level and that corresponding the production efficiency frontier. In this sense, the measurement of efficiency is based on a comparative process between the firm's position and its production frontier.

The production frontier traces the link between maximum level of production that a firm can produce by using its technical production combinations in the most efficient way. It reflects a producer's rational production behavior who seeks to avoid waste and to ensure best practices in the use of its resources. A firm is efficient if it is on this production frontier, i.e., from a given combination of the input that it holds, it produces the maximum of output, or also, it produces a given output quantity, using the minimum input quantities (Atkinson and Cornwell, 1994).

Measuring the degree of production unit efficiency thus makes it possible to know whether it can increase production without consuming more resources, or reduce the use of at least one input while maintaining the same production level.

Generally, a distinction is made between technical efficiency, allocacitve efficiency and efficiency of scale. Technical efficiency refers to the firm's ability to be on the production frontier in the sense that it produces maximum output by using a certain quantity of inputs. Allocation efficiency reflects the firm's ability to use its inputs in optimal proportions, reducing its production costs given their respective prices. Scale efficiency implies the firm's ability to take advantage of economies of scale and to have a minimum efficiency size that minimizes its long-term average cost (Murillo Zamouranou, 2004),

The decomposition of this efficiency notion into technical, allocative and scale efficiency is highly essential to the decision-making of companies to choose the best actions likely to improve their efficiency level and to fill their insufficiency either in the resources allocation, or in the choice of the technical combination of production or also the firm size.

Generally, two approaches are used to estimate the efficiency frontier and to measure the efficiency score of a firm: the parametric and the non-parametric approach.

The parametric approach consists in estimating a given objective function for the firm (production, cost or profit function) by assuming beforehand a given functional form between the variable to be explained and the explanatory variables. The estimation of these functions is based on econometric techniques.

The non-parametric approach uses linear programming techniques to identify the set of optimal production techniques that maximize the output level of the firm (Charnes et al., 1995). It assumes a non-parametric and non-linear relationship between the input and output variables without the need to impose any restrictions on the form of the objective function. This method is known by the Data Envelopment Analysis (DEA) method. It has the advantage of determining the production frontier for a multi-input and multi-output industry without any additional restrictions and measuring the improvement margin that an inefficient firm can bring either to its consumption of inputs and / or to its production of outputs. In this sense, the DEA method is an essential tool for making the best decisions in terms of the resources allocation and determining the size of the firm's optimal efficiency.

Several versions of this DEA model have been presented and tested in empirical work and which differ according to both input or output orientation[1] of the model, as well as the nature of the constant or variable returns to scale. Depending on the version to be used, the results and their interpretations differ.

Under the assumption of constant returns to scale, Charnes et al, (1978), developed a DEA CRS[2] model. In its input orientation, this model is expressed by a constraint maximization program presented as follows[3]:

$$\text{Min } \theta_i$$
$$s.t$$
$$\theta_i X_i - \sum_{h=1}^{H} \lambda_h X_h \geq 0 \quad \vee \text{ h = 1…H}$$
$$\sum_{h=1}^{H} \lambda_h Y_h - Y_i \geq 0$$
$$\lambda_h \geq 0$$

Where X_i and Y_i are respectively the vectors of exploited inputs and ouput produced by the DMU_i that we are looking to evaluate its efficiency level.

X_h and Y_h are respectively the vectors of exploited inputs and output produced by the other DMU_h for any $h = 1, \dots, H$; $h \neq i$.

λ is a vector composed of constant H's called multipliers that indicate how the DMUs combine to form the efficiency boundary against which the i^{th} decision unit will be compared.

θ_i is the efficiency score of firm i. This score is between 0 and 1.

If $\theta_i = 1$, firm i is designed as technically efficient.

If $\theta_i < 1$, firm i is technically inefficient.

[1] The input orientation aims at minimizing inputs without modifying the quantities of outputs. It shows us the margin for reducing the input quantities to produce the same quantity and combination of outputs. Whereas the output orientation aims at maximizing outputs for a given level and combination of inputs. It tells us how much room there is to increase the outputs without changing the inputs.

[2] This model is also known as DEA CCR in relation to the names of its founders Charnes, Cooper and Rhodes.

[3] For a more intensive analytical development of the DEA method, interested readers may refer to Seiford and Thrall (1990), Ali and Seiford (1993) and Charnes, Cooper, Lewin and Seiford (1995),

However, this DEA-CRS model is generally restrictive because in reality it is unlikely that companies operate at their optimal size of efficiency and in an environment of pure and perfect competition. Furthermore, this model confuses technical efficiency with scale efficiency.

This gap was filled in 1984 by Banker, Charnes and Cooper (1984) who proposed the DEA model under the assumption of variable returns to scale. This DEA-BCC or DEA-VRS (variable return scale) model provided a clear precision to the measurement of efficiency by decomposing total efficiency into pure technical efficiency and scale efficiency. The efficiency score calculated according to the DEA-VRS method alone indicates pure technical efficiency without the scale effect. The scale efficiency score can be deduced following the application of the DEA-CRS method.

According to Coelli et al (1998), the scale efficiency score is determined by the ratio between the efficiency scores calculated according to the DEA-CCR and DEA-BCC method.

$$\mathrm{SE} = \frac{\theta^{*\mathrm{CRS}}}{\theta^{*\mathrm{VRS}}}$$

Where SE is scale efficiency. With, $0 \leq .\ \mathrm{SE} \leq 1$.

Scale efficiency is only achieved when both CRS and VRS efficiency scores are equivalent. In other words, if both DEA-CRS and DEA-VRS models lead to the same result, this indicates that the firm operates at its optimal size and that the returns to scale are constant.

Note that the version of the DEA model with variable returns to scale (DEA-VRS) is based on the same optimization programs as those applied in the DEA-CRS model, but with an additional assumption about the convexity of the production set. This assumption can be systematized by the condition: $\sum_{j=1}^{N} \lambda_j = 1$.

This additional constraint implies that inefficient firms must be compared with those having the same production scales.

3. Variables choice and data presentation

Several indicators were selected in the literature review to evaluate the output of CPT, the most commonly used of which are Seat--kilometers offered (SKO) and passenger-kilometers transported (PKT). The difference between these two indicators lies in the technical or commercial nature of a CPT company's offer. The first indicator refers to the capacity offered by the company, while the second indicator refers to traffic, i.e. the number of passenger-km actually carried.

As long as the transport service is non-storable and its offered capacity is rigid at least in the short term, these two indicators are distinct and their ratio indicates the average bus occupancy rate. This rate is an indicator of both the quality of the services offered and the efficiency of the use of the capacity offered as well as the profitability of the trips. An occupancy rate that exceeds 100% indicates overuse of the capacity offered, which leads to congestion, accelerated depreciation of equipment and a deterioration of service quality. A low occupancy rate reduces the company's profitability and deprives it of economic density (Matas and Raymond, 1998).

Some authors like Viton 1997; Margari et al., 2007; Odeck, 2008, and so on, justify their choice of SKO output on the one hand, by the objective of studying the technical efficiency, which aims to maximize the capacity offered given the resources, and on the other hand, by the fact that the demand escapes the act of the firm. It depends on several other factors relating to the socio-economic system. These studies incorporated the commercial output evaluated in PKT as a control variable to explain the efficiency gap between CPT companies.

However, other studies (Sampaio et al, 2008; Karlaftis and Tsamboulas, 2012;) have used aggregate commercial output (PKT) which better reflects the company's ability to exploit its offered capacity in a more rational way. They consider the SKO indicator to be a measure of input and not output.

In fact, this offered capacity is calculated as the product of the number of journeys made per unit of reference time, the average bus capacity and the average distance of a journey. This SKO remains constant particularly for regular traffic at least in the short term, where the company has not made any investments to reinforce its bus fleet or extend its route network. It is thus planned in advance, particularly by the public authorities concerned when the company is public in nature. It does not reflect the real output of the company and it cannot evolve in line with the factors of production or the control factors that explain inefficiency.

Other studies (Levaggi, 1994; García Sánchez, 2009; Li et al., 2013; Zhu et al., 2016) have disaggregated transport output as a function of network characteristics in terms of the number of lines, average distance of trips, number of stations, as well as the quality of service offered in terms of commercial speed, average occupancy rate, empty distance, frequency, etc.. This output, described as hedonic, thus makes it possible to diversify the services offered by a company via the technical characteristics of its offer and to properly detect the sources of performance differences between CPT companies. It better describes the reality of

the multi-product production process of a transport firm by reducing the degree of ambiguity inherent in the aggregation of output and the degree of complexity related to its extreme disaggregation (Spady and Freidlander, 1978).
Regarding the input variables, most studies adopt the three classic inputs of any firm such as capital which has been evaluated differently from one study to another, fuel and labor.
However, to better explain the sources of the efficiency differences between the CPT companies, several other variables known as "control variables" were retained either as inputs and incorporated directly into the DEA model or non-discretionary variables used as explanatory variables for efficiency and which are used in a second linear regression model to express their significance and explanatory power.
These control variables describe the environment in which the firm operates and witch is outside of decision makers control. In fact, CPT firms operate in different environments that influence both their supply and demand conditions as well as their level of efficiency. This environment can be associated with network characteristics such as network length, average age of the fleet, density or number of stops, etc, traffic conditions in terms of road congestion (commercial speed, peak traffic ratio, station stop times, etc.), quality and density of road infrastructure, motorization rates, density of demand as assessed by population density, regional economic growth, standard of living, governance regime and ownership of capital, level of liberalization, etc. the market structure as assessed by the number of competitors, the degree of concentration, the pricing structure, etc. and technological change represented by a time-trend variable.
These variables are shown to be determinants of the efficiency of the company that influence the cost of operating bus and determine the market potential of the company. Their introduction allows both to take into account the heterogeneity of the environment in which the firm operates and to provide more specific informations about the performance structure of the sector.
Thus, there is great diversity in the choice of these input, output and control variables to test the level of efficiency of a CPT company without there being a consensus on commonly accepted variables in this industry.
Generally, the choice of these variables depends on the objective of the study, the performance criteria selected by the firm and the availability of data (Hirschhausen and Cullmann, 2010).
In fact, the concept of efficiency can only be closely linked to the objectives assigned by the CPT companies. On the one hand, the latter seek to maximize the use of their capacity (maximizing the occupancy rate) and avoid empty returns or trips, and on the other hand, to satisfy the qualitative requirements of users in terms of speed, minimizing waiting time at stops, accessibility, reliability, etc. (Hirschhausen and Cullmann, 2010). These qualitative requirements vary according to the conditions of CPT's services supply in terms of number of lines served, their distances and configurations, the number of stops and their location, frequency, speed, traffic conditions, density of demand, etc.
In our study, we chose as output variables, the number of passenger-kilometers transported (PKT) measured by the product between the number of passengers actually transported and the total distance travelled by all buses during a year. This output better reflects the industrial reality of the sector because it indicates the attractiveness of public transport and takes into account the economic motive for providing services (Berechman 1993).
At the input level, we have chosen three variables that are indispensable for any economic analysis, which are capital, labor and energy represented respectively by the number of buses (buses), the total number of employees including drivers, administrative staff and technicians (employees) and fuel consumption (energy) evaluated by the tonnage of fuel consumed per year.
In addition to these traditional input variables, it seems necessary to add other attribute variables illustrating the characteristics of the network and the quality of the services offered. These attributes are multiple and their selection varies according to the purpose and availability of the data. For this study, we have chosen the following variables: Seat- Kilometer Offered (SKO), which is the product of frequency, number of buses, their capacity and total distance travelled per year, Occupancy Rate (OR), number of routes (Lines) and age of the fleet (Age).
The choice of these output and input variables is dictated both by the lessons learnt from the literature review on the subject and by the availability of data.
The data used in this study have the panel data structure of 13 regional bus transport companies covering the only urban network over 9-year (from 2009 to 2017), i.e. a total number of 117 observations. These observations will be conceived as decision units (DMU's) that transform certain quantities of inputs into an output.
In Tunisia, the collective passenger transport sector is managed by these 13 public regional bus transport companies. It is thus highly regulated and segmented into a set of production units forming a monopoly situation with several establishments. Each company has an urban, interurban and suburban transport network whose configuration and size are predetermined by the concerned authorities according to the demographic, economic and urban characteristics of each region.
Table 1 presents a descriptive statistics for these inputs, output and attribute variables.

All this data relating to the inputs, output and attribute variables of each enterprise were collected from the annual activity reports of each enterprise.

Table 1: Analysis of descriptive statistics

Variable	Observation	Average value	Standard-Deviation	Min	Max
Bus	117	293	284.4282	101	1270
Employees	117	1049	1574.837	222	7755
Enery (ton)	117	5443	5691602	1541	29300
PKT (10^6)	117	926	2.05	35.3	1300
SKO(10^6)	117	538	1.07	35.4	492
Lignes	117	198	74.011	54	377
Age	117	8.58	1.491667	5.11	12.83
OR	117	1.7	0.51	0.85	3.26

The table of descriptive statistics shows a great variance between the sizes of the firms and a large dispersion in the sample. For example, in terms of capital, we note a large variation where the company STT has the highest number of buses with 1270 buses unlike the Beja company (SRTB) which has the lowest number with 101 buses.

In addition, commercial activity appears to be much more active in Tunis with a traffic of 4,300 million PKT against only 60 million PKT in Kasrine. The STT alone accounts for 45.2% of total urban transport traffic by bus in Tunisia. The first four companies serving the most developed regions of Tunisia occupy 81% of the total traffic and monopolize 83% of the total capacity offered.

4. Measuring the technical efficiency of public passenger transport companies in Tunisia

The objective of this section is to calculate the technical efficiency scores of the public transport companies in Tunisia and to determine their various sources by applying the DEA method under constant and variable returns to scale according to an input orientation. The choice of this input orientation of the model is dictated by the objective of transport companies that seek to solve a specific problem of poor management or use of resources.

Table 2 presents the average scores for total efficiency, pure technical efficiency and efficiency of scale[4]. We recall that total technical efficiency is induced by the DEA-CRS model. While, the pure technical efficiency is calculated following the processing of the DEA-VRS model, and the scale efficiency is equal to the ratio between CRS and VRS scores.

According to the obtained results, the average score of total efficiency (CRS) recorded in our sample is rather low (0.527) indicating that the CPT system in Tunisia is inefficient in its totality. This average score of technical efficiency has stagnated over time, but for most of the studied companies, it marked a decline, particularly from 2011 onwards. For example, for the firm STT, this score decreases from 1 to 0.66 between 2010 and 2015. Knowing that the year 2011 was the year when Tunisia knew a revolution after the autocratic regime, which reigned since 1987. This revolution has created an upheaval in the operating mechanisms of public enterprises and consecutive strikes by their staff demanding an improvement in working conditions and a wage increase.

An efficiency score equal to 1 indicates that the company is technically efficient in the sense that it minimizes the exploitation of its resources in order to produce a certain level of output evaluated in terms of PKT. While a score less than 1 indicates that the company is inefficient and suffers from over-use of its resources or also a waste in the exploitation of its means of production.

According to our results, no firm manages to reach the CRS technical efficiency frontier during the analysis period. Only 2 firms (SRT Bizerte and STT Tunis) had a total technical efficiency score equal to one in different periods (SRT Bizerte had full efficiency in 2016 and 2017 and STT had this score in 2009 and 2010). However, these companies were unable to maintain full efficiency during the analysis period.

Table 2: The results of efficiency scores of the different firms

Firme	Average total technical efficiency score (DEA-CRS)	Average score of pure technical efficiency (DEA-VRS)	Average scale efficiency score
SORETRAK	0.407789	0.951767	0.428787
SORETRAS	0.475005	0.95185	0.502514

[4] The MaxDEA 7 Basic software was used to determine the efficiency scores.

SRTGN	0.633086	0.917529	0.697052
SRTKasserine	0.318339	0.994555	0.320089
SRTB	0.835366	0.989603	0.843812
SRTKef	0.348926	0.977471	0.356864
SOTREGabes	0.552601	0.903284	0.617398
SRT Béja	0.406608	1	0.406608
STS	0.805409	0.872314	0.847584
SRT Gafsa	0.453621	0.890915	0.514372
SRT Jendouba	0.278612	0.995249	0.280019
SRT Médenine	0.579347	0.994765	0.582214
STT	0.82353	0.997984	0.825112
Moyenne	0.527018	0.956714	0.5555712

We also note that there is an important difference between the efficiency scores that vary between a maximum value of 1 and a minimum value of 0.26, indicating a great heterogeneity in the efficiency of the CPT companies in Tunisia. Some companies show a high degree of efficiency and others record low scores.

We can distinguish three groups of companies according to their average total efficiency score: Three companies (Société des Transports de Tunis (STT), Société de Transport du Sahel (STS) and Société Régionale de Transport de Bizerte (SRTB)) have a high efficiency score of more than 80% and are qualified to be efficient. Three companies (SRTGN, SOTREGabes and SRT Médenine) with an average efficiency score of more than 50%. The remaining companies (7 companies) qualified as highly inefficient with an efficiency score of less than 50%.

However, the average level of pure technical efficiency (VRS) is high. It is close to 1 for all companies and years. The average score recorded for all the DMU's in our sample is 0.95, indicating that the CPT system in Tunisia operates efficiently in terms of resource allocation (pure technical efficiency) with potential for improvement. Almost all the firms (at least for a certain year) are placed on the efficiency frontier with variable returns to scale.

Similarly, the differential observed between the pure efficiency scores is not very large, indicating that CPT firms have homogeneous levels of pure efficiency.

The discrepancy between the pure technical efficiency score and the total efficiency score is due to scale inefficiencies. These inefficiencies of scale are induced by the under-optimization (insufficient or over-capacity) of the company's size or rather that the size of the company (assessed by the bus fleet or the SKO or also by the number of routes served) is inadequate for the minimum efficiency size.

The average level of scale efficiency recorded for our sample is 0.55 and varies between 0.28 and 0.85. Generally, the firms with the highest total efficiency score are those that also have the higher score in scale efficiency.

Similarly, smaller firms show a significant difference between the two scores of pure efficiency and scale efficiency. This clearly indicates that scale inefficiencies are relative to the small size of firms.

Therefore, our results imply that returns to scale for small and medium-sized firms are increasing and that there is potential for improvement by exploiting economies of scale. In this sense, we suggest that small and medium-sized enterprises need to increase their size through a process of horizontal concentration by merging small enterprises that are geographically close.

These advantages of economies of scale in improving the efficiency of small firms have been confirmed by several studies that have shown that larger firms are technically more efficient than smaller ones (Berechman, 1993, Viton,1997; Odeck, 2008; Hirschhausen, and Cullmann, 2010, etc.). However, if the increase in the firm's available capacity is not well exploited, it greatly reduces its efficiency.

This size is all the greater the larger the company has a large bus fleet and its network is branched out into several lines. This network size is a source of both economies of scale and economies of scope. In fact, the CPT industry is highly capital-intensive, incorporating a very large share of fixed costs. These fixed costs will be better amortized over a larger number of the units offered. Moreover, serving several lines simultaneously, which illustrates the diversification of the output of a CPT company, proves to be less expensive than specializing in serving a single line because the company can better benefit from the common inputs used to offer transport services regardless of their geographical allocation. Similarly, this diversification improves the attractiveness of the company through its ability to better satisfy the diversified travel needs of citizens by offering them better accessibility and geographical coverage via an extensive and branched network.

Therefore, increasing this production capacity by purchasing new buses and creating new lines, will have a considerable influence on the efficiency of CPT companies. These investments are necessary to improve the quality, reliability, and security of the CPT system and to increase the demand for transport services.

SRT Jendouba firm has the lowest scale efficiency score equivalent to 0.28. While the transport companies of Sahel (STS), Bizerte (SRTB) and Tunis (STT) have the highest average score equivalent to 0.847, 0.844 and 0.825 respectively. This shows that these firms manage not only to optimize the use of their production factors but also to reach the optimal efficiency size.

Several endogenous factors have combined to explain these differences in efficiency between CPT companies in Tunisia.

Benchmarking results show that, on average, efficient companies compared to inefficient ones are more productive in terms of both labor and capital and energy consumption, than inefficient ones in terms of size. In fact, the average labor productivity as the average number of PKT produced by each worker in a company is 1712884 for the STT in 2017 while it is 121266 for SRTJ. Similarly, to produce one million SKO/year, STT requires only 1.2 labor units, while SRTJ operates 5.25 labor units.

Generally, the primary factor explaining the inefficiency of most of the CPT companies in Tunisia is the problem of overstaffing. The results show that, on average and across the entire period analyzed, CPT companies must reduce their workforce by 20% to reach the efficiency frontier. As an example, the SRTJ company is encouraged to reduce its workforce from 319 employees to 240. This shows that with a smaller number of employees, it can achieve the same level of production.

Because of their public nature, these companies have, since their creation reservoirs to absorb the unemployed, which has caused problems of overstaffing. The available capacity of the capital (bus) is largely insufficient to absorb the engaged workforce As a result, the marginal labor productivity will be negative and these enterprises thus operate outside the area of economic efficiency because production will be declining.

Several studies have emphasized this point and have shown that public companies in a monopoly position do not encourage their employees to make a significant effort because of the information asymmetry and the lack of profit-seeking that should lead these companies to be more rational and to minimize their production costs.

The second factor explaining the inefficiency of CPT companies in Tunisia is the high-average ages of the bus fleet. It exceeds 10 years old. According to our estimates, there is a negative correlation between the average age of the fleet and the output and consequently the level of efficiency.

The increase in the average age of the fleet negatively affects the productivity of the capital (bus), increases the energy consumption, destroys service quality and increases maintenance and operating costs.

The three most efficient companies (STT, STS and SRTB) have a bus fleet with a lower age than the average one (between 7 and 8 years). They took actions to rejuvenate their fleets. In addition, these companies have a larger fleet of buses evaluated by their offered capacity (number of seats available). Therefore, the large productive capacity of a CPT firm widely explains its high level of efficiency.

Transport companies with an aging bus fleet suffer from excessive energy consumption and an increase in the number of technical breakdowns of buses. Consequently, this leads to a decrease in the rate of bus availability and production capacity. According to SRTJ's activity reports, the breakdown rate over 10,000 kilometers is passed from 1.72 in 2009 to 2.21 in 2017 recording an evolution of 26.5% following the aging of its bus fleet whose average age exceeds 10 years. The availability rate of buses has increased from 38.5% in 2009 to 10.2% in 2017.

This rather high average age lies particularly in the inability of most companies to generate self-financing necessary to renew their bus fleet. These firms suffer from a budget deficit and lack of autonomy in decision-making. Otherwise, the subventions granted by the State to these companies are insufficient even to cover their operating costs. To be able to cover their budget deficits, both these companies and the public authorities must find solutions and provide the necessary financial resources to renew bus fleets and increase production capacity.

In terms of energy consumption, several studies such as Zhou et al. (2014) have shown that there is a positive correlation between energy consumption and PKT growth. However, in our study, the fuel consumption for a certain companies increased without its output having evolved. This can be explained by, on the one hand, empty returns induced by a bad network configuration and a bad scheduling of departure times, on the other hand, by the extension of the lines with low density of traffic, and finally, by the age of the bus park.

For instance, the average energy consumption must be reduced for the SRTJ Company from 2205704 to 519385 liters, ensuring the same volume of traffic.

Since the end of 2012, the most efficient companies have committed themselves to a program to rationalize energy consumption in collaboration with the National Agency for Energy Management. They have adopted a set of actions to save fuel consumption, such as ensuring direct monitoring of bus engine conditions via an operating assistance system, strengthening preventive maintenance, giving training courses to sensitize agents and improve the behavior of drivers during driving hours.

As in many works that tried to disaggregate transportation output (Levaggi, 1994 ; Viton, 1997 ; Li et al, 2013 ; etc.), our results also show that the characteristics of the transport offer have a greater impact on the efficiency score than conventional inputs. From where the interest of their integration into the assessment process to better explain the technical efficiency gap between companies. In fact, the number of lines has a positive effect on the technical efficiency of CPT companies. Firms with a larger network of lines that maximize the geographic coverage of the population served are more efficient. Firms with a wider network of lines maximizing geographic coverage of the population served are more efficient.

The three most efficient firms STS, STT and SRTB have a network composed respectively of 325, 243 and 217 lines, compared with the least efficient firms such as SRTKasserine, SRTKef and SRT Jendouba, which have the least extensive network with 101, 96 and 104 lines respectively.

Companies also need to increase their attractiveness especially of full-rate customers who are currently escaping their demand because of the poor service quality of the firms. This quality can be appreciated in our model by the indicator of the occupancy rate. This rate reflects the adequacy between the supply and demand of transport. If the demand exceeds the supply, the occupancy rate will be high, indicating that the bus capacity available to users is insufficient to meet the user's travel needs. This imbalance creates overload and congestion of the buses which deteriorate the service quality, amortize bus faster and reduce the technical efficiency of the companies.

According to our database, the average occupancy rate of our sample is 1.7 and varies between 3.26 (Tunis) and 0.85 (SRT Jendouba). So, most of our CPT companies even the efficient ones suffer from bus overload while registering occupancy rates are superior than 1.

This inefficiency is illustrated through the reduction of the number of paying travelers and their substitution by schoolchildren and students. Paid users manifest a reluctant behavior towards the choice of the bus mode compared to the collective taxi which invades more and more the market of CPT.

5. Results and interpretation of the Tobit regression

Other than endogenous factors relating to the technical allocation of resources, the efficiency gap observed between the CPT companies. It is explained by other exogenous factors relating particularly to the urban environment in which each firm operates. This environment varies from one agglomeration to another in terms of population density, motorization rate, level of development, urbanization, etc. It can affect both the demand for the company and its supply conditions. However, this environment is outside the scope of the firm's activities, but it can have a significant impact on both the firm's operating costs and its level of efficiency.

To take account of this external heterogeneity between companies, we will incorporate these control variables into a linear regression model to estimate and explain their contribution to determining the level of efficiency of a CPT company.

The explanatory variable will be the efficiency score already calculated in the first estimation of the DEA model. Since these technical efficiency scores take values between zero and one, we use the Tobit model because it can account for censored data (Tobin, 1958).

The model used in this framework is expressed as follows:

$$SE_{it} = \alpha_0 + \sum_{i=0}^{N} \alpha_i Z_{it} + \varepsilon_i$$

SE_{it} represents the efficiency score of company i at date t. These scores are derived by applying the DEA model in its CRS and input orientation version.

Z_{it} it is the vector of explanatory variables

β: The vector of parameters to be estimated

ϵ_i : The random term that follows a normal distribution of zero mean and constant standard deviation: $\epsilon_i \sim N(0, \sigma_\varepsilon)$

7 non-discretionary variables were selected, divided into two groups: variables characterizing each company's network that influence its supply conditions, such as average network length and road density. Variables characterizing traffic which influence demand, such as population density, motorization rate, number of companies and share of student traffic in the total traffic of each company.

The following table describes the statistical characteristics of all these variables

Table 3: Presentation of Tobit regression data

Variable	Average value	Min	Max	standard deviation
SE : Efficiency score CRS	0.572	0.226	1	0.542
Z_1 : Road density	0.069	0	1	0.05
Z_2 : Number of companies	31633.44	1115	323381	3163344
Z_3 : Population density	303.82	3083.7	3.72	615.98
Z_4 : Motorization Rate	0.091	0.025	0.34	0.154
Z_5 : Average network length	56.41	24	97.7	19.814
Z_6 : share of student traffic	0.69	0.46	0.89	0.106

The results of the analysis of this estimate are presented in the table below[5].

Table 4: Tobit estimation results

	Coefficient	P-value
Road density	0.004519	0.366
Number of companies	-0.29	0.000
Population density	0.0166	0.000
Motorization Rate	-1.257	0.412
Average network length	-0.00892	0.015
share of student traffic	-0.384	0.62
Constant	0.435	0.001
Observation: 117 Log likelihood: -12.3647 Pseudo R^2 = 0.825		

The model has considerable statistical and economic significance. Almost all the explanatory variables account for 82% in explaining the evolution of the technical efficiency score.

According to Table 4, population density significantly and positively affects the efficiency score. In this context, the CPT companies located in densely populated cities are favored and show a better efficiency in less populated cities. This population density presents the potential demand for transport and identifies the relevant market for CPT. Additional demand induced by population growth will enable the company to fill its buses better, avoid empty returns and increase the bus turnover rate. However, for a constant supply capacity, this increase in demand is likely to have the opposite effect on bus overuse and service quality. Therefore, the supply of CPT must also follow quantitatively and qualitatively the evolution of this demand.

The inefficiency of some CPT companies, induced by low population density, has been demonstrated by several studies such as those of Margari et al. 2007; Wang et al. 2015; Garcia Sanchez 2009, etc.

The estimation results also show a positive correlation between road density and efficiency score. However, this correlation is very weak. Road density was calculated as the length of roads per agglomeration on its surface. It indicates the availability and quality of the road infrastructure. This infrastructure presents the support on which buses circulate.

Its availability and quality necessarily determine of maintenance, depreciation and even operation costs of the buses. These costs will be more expensive as the quality of the infrastructure will be poor. Likewise, this quality of infrastructure conditions the fluidity of urban traffic and affects the commercial speed of buses and their technical condition.

Road congestion due to lack of sufficient infrastructure and lack of a bus prioritization system (specific site) reduces the commercial speed of buses and negatively affects both the quality and quantity of services offered. It should also be noted that the creation of a new road makes it possible to promote urban sprawl in the region in question, promote mobility and create additional transport demand, part of which will be captured by public transport.

[5] The estimation method used is ordinary least squares. Several studies have shown that this method is sufficient to explain the efficiency score (Hoff, 2007,; McDonald, 2009).

The motorization rate reflects the availability of a private car for households in a region. It implies both the intensity of intermodal competition (between bus and private car) and the fluidity of traffic. Indeed, above a certain level of traffic, an increase in the number of private car increases road congestion and reduces the commercial speed of buses. Low commercial speed bus is a source of direct additional costs for the company in terms of fuel consumption, reduced bus turnover and deterioration of service quality through longer journey times. Hence the negative effect of the motorization rate on the technical efficiency demonstrated by our model and explained primarily by its effects on congestion and reduction of commercial speed.

Second, high rate of motorization implies a rougher level of intermodal competition that favors the private car. The two modes are substitutable and any increase in the share of private cars in citizens' journeys implies a decrease in the share of bus transport. The decline in the share of CPT actually observed in all regions is explained particularly for the dominance of private cars and informal transport in users' journeys thanks to their advantages in terms of speed, availability, comfort and punctuality.

However, the coefficient associated with the number of firm is negative, implying that when the number of firm in a region increases, the technical efficiency of the regional CPT system decreases. This can be explained by the much lower nature of collective passenger transport, particularly in Tunisia. In fact, the number of firm variable has been included to indicate the level of development and wealth of the region. More than the number of firms grows, more than the employability grows and the standard of living of the citizens improves. Particularly paying users (who pay the full price) will be encouraged to change their modal choice from bus mode to other more reliable alternative modes (private car or taxi) (Quinet, 1998).

The mean network length variable is negatively correlated with the efficiency scores. This is explained by the fact that an extended network does not necessarily imply a higher number of passengers because the large proportion of travelers move in the urban area of the city at short distances and this traffic decreases with distance. Generally long-distance lines are of a suburban nature, reserved for serving rural areas on the outskirts of cities and characterized by low traffic density and low frequency. Their occupancy rate is low, journey times are high and bus turnover is low. They require more inputs (bus, work and energy) to be guaranteed, but they imply low profitability. They are operated to a large extent for purely social reasons in order to ensure accessibility for both high and other users to shopping and service centers located in the city.

According to our estimates, more than the share of student traffic grows, more than the level of efficiency of the companies decreases. Generally, school traffic is the highest for all transport companies. The average share of school traffic in our sample is around 69% and varies between 46% (STT) and 89% (SORETRAK). However, this traffic is the least profitable. In fact the subscriber tariff represents only 10% of the full price paid by a normal passenger. In the absence of sufficient supply capacity and self-financing to renew the obsolete bus fleet, the increase in the number of pupils and students transported may inflate the output evaluated in PKT, but destroys the financial profitability of companies. The latter record a loss of customers paying the full price who can better guarantee that operating costs are covered. In fact, we note that CPT companies are losing their paying clientele to the detriment of students, whose numbers grow from one year to another by an average of more than 6%.

Unfortunately, these public companies, unlike private companies, do not select their clients. They must offer a public transport service that meets the principles of social equity and territorial universality, even at a loss. In return, they are supposed to be subsidized by the state. But these subsidies are largely insufficient for them to cover their operating costs and increase their production. These companies have to find a compromise between the obligation to provide public services and the need to make their activity profitable and improve the quality of their services. They must not reduce the number of subscribers, but they must combat the flight of paying users and increase their number.

In order to overcome this deficiency, some authors (Li et al. 2013) have proposed the separation of school traffic from paying passenger traffic by providing special planned traffic at specific time margins either for schoolchildren or for some establishments and/or industrial enterprises (conventional transport). They may also limit the number of trips of subscribers according to their essential needs in order to rationalize their bus use. These solutions can increase the attractiveness of buses, reduce their overloading, optimize their rotation, improve the quality of service and increase the profitability of trips.

So we can therefore associate several sources of inefficiency in the Tunisian CPT sector, which are related to the poor allocation of inputs, the mismatch between the size of the industry and demand, and exogenous factors relating particularly to the size of the region and its level of equipment and motorization. These two factors may constitute limits to the increase in the size of a firm so that it can benefit from scale and network effects and be able to produce its services at the lowest cost and with better quality. They reduce the competitiveness of this mode of transport compared to road modes.

Consequently, it is essential to take account of these regional specificities in order to properly allocate the volume of investment in transport equipment and subsidies between regions and companies.

CONCLUSION

The public transport sector is an indispensable activity for the mobility of the population and the promotion of sustainable transport. Today it is facing increasingly tough competition from private individual transport and quantitative and qualitative changes in user requirements. As such, it is called upon to evaluate its efficiency in order to diagnose its current position and to determine and explain its sources of performance. This evaluation is an important instrument for providing some answers to the anomalies observed in the firms and for shedding systematic light on the efficiency differential between the CPT firms.

The need to measure the performance of the CPT sector has given rise to a wide range of theoretical and empirical approaches and studies that have enriched this field of research. In particular, these studies have adopted two approaches to empirical analysis: one based on parametric modeling (SFA model) and the other on non-parametric modeling (DEA model). The latter approach has shown greater performance in measuring a firm's technical efficiency score thanks to its flexibility and its ability to calculate the efficiency score with reference not to the average efficiency of the sample, but to the most efficient firms in the sample.

However, this non-parametric approach alone does not make it possible to take into account exogenous factors that may influence the firm's supply and demand conditions and consequently affect its efficiency level. It integrates in its model only the output and input vectors. In this case, the results obtained may be insufficient to explain the various sources of inefficiency in the firm. To fill this gap, recent work has opted for a two-stage model in which the DEA model is combined with a Tobit regression.

A second problem in assessing the efficiency of the transport industry is the identification of output. This service industry offers a variety of goods of varying quality that are distributed over a network. Aggregating this output into a single indicator does not reflect the true production process of the transmission company and limits the information and significance of the obtained results. Recent studies have tried to disaggregate this output by integrating the different characteristics of the network and quality of service into its definition and measurement. This disaggregation of transmission output has yielded more meaningful results and more operational information regarding the causes of efficiency differences between the transmission companies studied.

The aim of our work is to assess the level of technical efficiency and scale of Tunisian CPT companies, to identify endogenous and exogenous factors that may explain their inefficiency and to analyze their economic implications on the sector's performance.

Our approach is based on a two-stage DEA model. In the first stage, we used the classic DEA model in its two versions CRS and VRS under input orientation, to calculate the technical efficiency and scale score of each company throughout the study period. This model was applied to a sample of 117 MUMS's composed of panel data on the 13 Tunisian public passenger transport companies covering the single urban network, over a 9-year period from 2009 to 2017.

The output selected in this model is of the hedonic type combining an aggregate output evaluated in PKT with the characteristics of the offer such as the Seat- Kilometer Offered, the occupancy rate, the number of lines, and the age of the fleet. At the input level, we chose three standard variables such as the number of buses, the number of employees and the fuel consumption.

After comparing the companies in our sample in terms of total technical, pure technical and scale efficiency scores, and proposing the necessary adjustments in resource allocation so that these companies could reach the CRS efficiency frontier. We proceeded to the second step which consists in estimating these efficiency scores according to a number of control variables reflecting the economic, geographical and demographic environment in which these companies operate.

A variety of explanatory variables were incorporated to explain the efficiency gaps observed between the MISPs in our sample, such as road density, number of firms, population density, motorization rate, average network length and share of student traffic.

The results of the first model showed, on the one hand, a total technical inefficiency of the entire VCT system in Tunisia with an average efficiency score of 0.52. On the other hand, the results of the second model showed a total technical inefficiency of the entire VCT system in Tunisia with an average efficiency score of 0.52. The results of the third model showed a total technical inefficiency of the entire VCT system in Tunisia with an average efficiency score of 0.52. In the other side, a strong heterogeneity in the efficiency scores between the companies. There are only three companies near the CRS efficiency frontier such as STT, STS and SRTB. While the others scored high levels of inefficiency.

This inefficiency lies particularly in overstaffing and inefficient use of resources, under-capacity, and overloading of buses that reflect poor quality of service and imply deteriorating bus conditions and high failure rates.

The most efficient transport companies are those with a more branched route network, a younger bus fleet, better labor and capital productivity by using less labor and rationalizing their bus use, etc. We also found that the largest firms have the highest level of efficiency.

Our results also showed that the CPT industry in Tunisia shows increasing returns to scale and that there is potential for improvement by exploiting economies of scale particularly for small and medium sized enterprises.

Similarly, and in line with several studies, our results have shown the importance of attribute variables that characterize the supply of transport services in explaining the efficiency gaps between the studied firms.

The results of the second model showed that there are several exogenous factors that characterize the technical, demographic and economic environment in which firms operate that significantly affect efficiency. They indicate that the average length of the network, the motorization rate, the number of firms and the share of pupil traffic, negatively affect the efficiency score, while road and population density have a significant and positive impact on the technical efficiency level of Tunisian CPT firms. This efficiency is all the higher as the population served is dense, the road network is well maintained, the motorization rate is low, the lines are of short or medium distances and the share of student traffic is low.

These results will necessarily have implications both for the authorities involved in the regulation of the CPT sector and for the companies producing bus services. As far as the public authorities are concerned, their objective is to meet the increased needs of the population in terms of urban transport under the best conditions of cost and quality of service. As has already been shown, this performance is dependent on environmental conditions directly related to the territorial management of local authorities, which must provide the necessary infrastructure equipment so that the CPT sector can carry out its functions in the most efficient way.

Furthermore, public authorities can use this efficiency ranking to allocate subsidies and investments by favoring the most efficient companies and introducing an incentive compensation mechanism based on the level of efficiency achieved (Santos et al. 2013).

For firms, efficiency assessment will enable them to identify their main sources of inefficiency and to identify best practices and actions needed to remedy them. By comparing themselves with efficient companies serving as benchmarks, inefficient firms are called upon to adjust their size to critical size, to develop new services favoring specialized and cost-effective transport, to improve the technical state of their bus fleets to increase their availability, etc.

However, given the current loss-making financial situation of these companies and their supervisory bodies, fleet renewal and investment in new transport telematics are proving difficult. The strategy for reforming this sector should target, on the one hand, increasing the size of small and medium-sized enterprises through a process of horizontal concentration, on the other hand, selecting more profitable market niches (reducing or optimizing the use of school transport), and finally the possibilities of opening up to private investors through privatization or public-private partnership actions. This will encourage these companies to reduce their production costs, improve their management practices and diversify and improve the quality of the services offered.

It is true that our model did not take into account the governance factor or the nature of the firm's capital or even the market structure to explain the performance gap, since all the firms in our sample are public in nature and occupy a regional monopoly position, but several studies (Delhausse et al. 1992; Kumar. 2011) have revealed that the institutional factors of administrative management and capital ownership are sources of inefficiency and have shown that private management is more efficient than public management.

These issues relating to the choice of governance mode and more particularly to the selection of the type of contract between the authorities and the transport company will be the subject of our subsequent studies.

It should also be recognized that the calculated estimators are deterministic by ignoring the impact of statistical noise on the efficiency score. Our study can therefore be extended several times.

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