Antecedents of the Efficiency of Refrigeration Services´ Third-Party Logistics (3PL) Providers: A Study on Brazilian Market

Autoria

Antonio Carlos Rodrigues - antonio.rodrigues@facc.ufjf.br
Universidade Federal de Juiz de Fora (UFJF)/Departamento de Administração

Ricardo Silveira Martins - ricardomartins.ufmg@gmail.com
Centro de Pós-Grad e Pesquisas em Admin – CEPEAD/UFMG - Universidade Federal de Minas Gerais

Janaína Siegler - sieglerj2@nku.edu
Northern Kentucky University/College of Business

Roberta de Cássia Macedo - roberta.c.macedo@gmail.com
Centro de Pós-Grad e Pesquisas em Admin – CEPEAD/UFMG - Universidade Federal de Minas Gerais

Resumo

Economic growth increases the need for continuous improvement of logistic processes. In this context, comprehensive services and high-level operational performance are competitive advantages, with special attention to refrigeration services in the cold chain. This study's main objective is to determine the variables that significantly affect the efficiency of third-party logistics (3PL) providers of refrigeration services and propose ways to improve the competitiveness of specialized 3PLs. This study used Data Envelopment Analysis (DEA) and Tobit regression with unbalanced panel data from 2008–2015. The aim was to measure the impact of contextual variables on the scale efficiency (SE) of Brazilian 3PL providers of refrigeration services. The results showed that contextual variables such as stock control, tax support, transfer, enterprise resource planning (ERP), internet queries, radio tracking, and in-house routing systems positively affect SE. Moreover, 3PL providers that offer services that are more complex do not achieve better outcomes. The use of secondary rather than primary data limits this study's findings, particularly concerning the inputs, outputs, and contextual variables. These may not cover all aspects that are relevant to building and assessing an efficiency frontier. The study provided guidance for managers who wish to establish or adapt specialized 3PL structures and management systems in cold chains. This study helps to identify the main determinants of SE for 3PL providers of refrigeration services in an emerging economy. Further, it develops performance benchmarks for specialized logistics services.

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Abstract
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Keywords: Cold chain, Efficiency, Third-Party Logistics, DEA

1. INTRODUCTION

Economic growth increases the need for continuous improvement of logistics processes because customers seek better operational performance. In some sectors of economic activity, comprehensive services and high-level operational performance are competitive advantages, thereby prompting companies to focus on managing their supply chains as the core element of their competitive strategies. This approach requires the ability to coordinate, communicate, and collaborate with other companies within the supply chain (ZACHARIA; SANDERS; NIX, 2011). This aspect of logistics is known as the "cold chain".

In the cold chain, the correct temperature must be maintained in order to guarantee the quality of products from the moment of production to the time at which they reach the end consumer (LUO et al., 2016). These products can be perishable items such as food, which includes fruits, vegetables, fish, meat, and dairy products; health-related products such as medicines, material for examination, vaccines organs, plasma, and tissues; chemical products; and electronic components such as microchips (RUIZ-GARCIA et al., 2007; RUIZ-GARCIA; LUNADEI, 2010; ZHANG, 2007). Consequently, the term "perishable goods" refers to products that have short life cycles and that must be kept, transported, and distributed in a certain condition. Despite negative experiences in cold chain in the USA, investments in specialized cold-storage facilities in China, for example, to meet the growing demand among Chinese consumers for higher quality vegetables, fruits, cheeses, meats and frozen foods like ice cream (GRANT, 2017). For this reason, the concept of Cold Chain Management (CCM) has emerged. Additionally, the performance appraisal in the cold chain is a cumbersome task, because it has many features that set them apart from the other models of SCM (SHABANI; SAEN; TORABIPOUR, 2012).

Outsourcing the logistics function is a business dynamic of growing importance worldwide (SAHAY; MOHAN, 2006). Due to the increase in the scale of operations, shippers seek specialized operators. As noted by Maloni and Carter (2006), three reasons for outsourcing logistics are (1) service improvement, (2) cost reduction, and (3) a desire by the organizations that purchase logistics services to focus on their own competencies. In Brazil, the outsourcing market developed in the 1990s (FLEURY; RIBEIRO, 2003). However, the services that are offered are not standardized effectively; thus, it is important to develop mechanisms and tools that improve the process of selecting operators (WANKE, 2012; WANKE; AFFONSO, 2011). In academy, especially in emerging markets, this is an opportunity to consider the development and improvement of methods that professionals can use to support and improve their choices.

Brazilian shippers continuously express their desire for increasingly customized services. In response, the providers say that operational scale is still restricted and does not encourage a suitable level of investment. The slow revenue growth compounds the financial problem encountered by 3PLs as a result of already thin profit margin. With tight profit margins and increasing competition, a key to 3PL's survival is its ability to keep 3PL operations "lean." Sustaining lean operations, however, is not easy given mounting cost pressures emanating from rising customer expectations, fuel costs, insurance premiums, and expanded services. One way of improving the operational efficiency and the subsequent competitiveness of 3PLs is to emulate best practice 3PLs that can be identified by setting a reliable performance standard. Examples of such a standard are a financial audit, an industry norm, and a benchmark. Since a 3PL needs to measure its operational performance relative to its competitors and its previous years to continuously strengthen its market position, benchmarking seems to be the most suitable way of setting a reliable performance standard and then measuring the comparative operational efficiency of the 3PL (MIN; DEMOND; JOO, 2013).

Some techniques are already widely employed in the identification of suitable performance levels for logistics. Techniques that are more robust can contribute more decisively, and it has been seen that in recent years, operational research techniques have been employed in situations that require Data Envelopment Analysis (DEA) for comparative performance data in order to assess efficiency levels (COOPER; SEIFORD; TONE, 2007; COOPER; SEIFORD; ZHU, 2011). In this context, the current study aims to evaluate the Brazilian third-party logistics (3PL) sector for refrigeration services in an attempt to answer the following research question: What are the determinants of scale efficiency (SE) for major 3PL providers of refrigeration services in Brazil? In order to answer to this question, the study uses the DEA technique and Tobit regression with unbalanced panel data in order to measure the impact of contextual variables on the SE of the refrigeration sector.

The rest of this paper continues as follows. Section 2 discusses the cold chain and the application of DEA in the context of 3PL providers of refrigeration services. Section 3 presents a two-stage DEA model in detail and justifies the choice of SE as a means of assessing the impact of coordination processes in logistics performance. In section 4, the results are analyzed and discussed. Section 5 considers the managerial implications of the results, and section 6 presents the main conclusions of the study.

2. LITERATURE REVIEW

The development of logistics outsourcing has resulted in potential supply benefits to the customer either through cost reductions or capital investment, which improves the level of service and creates greater efficiency and operational flexibility (MALONI; CARTER, 2006;

ZACHARIA; SANDERS; NIX, 2011). With the spread of logistics outsourcing, many 3PL providers have emerged to offer basic services such as transport and storage (ZACHARIA; SANDERS; NIX, 2011). Compared with traditional services, 3PL services are more complex, encompass a broader range of functions, and are characterized by longer-term, mutually beneficial relationships (LARGE; KRAMER; HARTMANN, 2011). In Brazil, automotive, electronics, and aerospace companies hire 3PL providers that manage primary transportation, warehousing, and inventory simultaneously through the intensive use of IT. However, food, beverage, and fuel companies focus on 3PL providers that offer transportation services only (WANKE; ARKADER; FERNANDA HIJJAR, 2007).

A cold chain is a particular branch of a supply chain (SHABANI; SAEN; TORABIPOUR, 2012) that is known as a temperature-controlled supply chain (SAHIN et al., 2007). It is a complex and dynamic system that involves time restrictions to ensure the validity of raw materials and perishable products; long, complex processes that comprise production, transportation, cold storage, security concerns, and the integrity of products (ARAMYAN et al., 2007). Flow control and storage extend from one or more points of origin to production sites, through distribution networks, and to the places of consumption in order to meet customer requirements.

Moreover, cold chain management involves the integration of existing business activities, including special activities for the preservation of perishable goods along the value chains, in which the suppliers of certain raw materials or semi-product production cells appear to create value for the final consumer (BOGATAJ; BOGATAJ; VODOPIVEC, 2005). A cold chain ensures that a variety of foods, pharmaceuticals, and chemicals do not suffer from degradation, inappropriate temperature exposure, humidity, light, and particular contaminants in order to keep them frozen, chilled, and fresh (JOSHI; BANWET; SHANKAR, 2009).. A cold chain also has many features that set it apart from a typical supply chain management (SCM) model. These features include shelf-life limitations, production in different seasons, production facilities and equipment such as refrigerated transportation, refrigerated storage and depots, traceability, and the quality and safety of products (ARAMYAN et al., 2007; SHABANI; TORABIPOUR; SAEN, 2011).

Studies on Supply Chain Management (SCM) have dedicated inadequate attention to those products that have limitations such as shelf life, need to special equipment and facilities for sales, storage and distribution and so on (SHABANI; SAEN; TORABIPOUR, 2012). A cold chain is regarded here as a set of equipment together with interdependent processes (ZHANG, 2007) that are managed in accordance with the principles of the 3Ts—time, temperature, and tolerance – in order to reduce waste and ensure the quality of fresh products (HUANG; XIE, 2007), which are distributed at a specific time (RUIZ-GARCIA; LUNADEI, 2010).

In this regard, the fundamental difference between a chain of non-perishable items and a cold chain is the risk of the loss of product value, in both financial and quality terms, during the transportation from a supplier to the end consumer (JOSHI; BANWET; SHANKAR, 2009). The typical infrastructure used for a cold chain usually consists of pre-cooling facilities, storage and refrigerated transport, packaging, and traceability through information technology (IT) (MONTANARI, 2008).

The literature on cold chains describes the strong dependence among some of the attributes that impact cold chain performance. However, the influence of interrelations among them on cold chain efficiency is not well addressed. When not properly considered, such attributes can be

inhibitors that may cause deteriorations in cold chain quality, hygiene, and efficiency. In this context, Joshi et al., (2009) highlight some relevant factors that affect cold chain performance. These are (1) food safety, (2) temperature control, (3) traceability, (4) facilities, (5) IT, and (6) standardization. Advancements on the use of technology have been recently addressed.

The appropriate reverse flow of final products that are unfit for use also guarantees the integrity of products that are subject to food safety issues. In this sense, it reduces or eliminates the quality loss of perishable products that is attributed to the growth of bacteria such as botulism, listeria, and salmonella. For that, it is necessary the monitoring and maintenance of perishable goods require efficient equipment with special features, suitable operating modes, and an appropriate information system because temperature control systems help with the effective management of product quality to inhibit the growth of microorganisms that spoil food (JOSHI; BANWET; SHANKAR, 2009; SAHIN et al., 2007; SHABANI; TORABIPOUR; SAEN, 2011). It is also important to mention that the right temperature of the system depends upon how items are transferred through the cold chain. Thus, data collectors, color changing labels, and radiofrequency equipment are used to monitor temperatures (SHARMA; PAI, 2015).

Traceability is another important component in the cold supply chain management. Traceability is the detection and monitoring of products throughout a supply chain (JOSHI; BANWET; SHANKAR, 2009). Traceability logistics is made possible using IT in a cold chain (WILSON; CLARKE, 1998). For example, radio-frequency identification (RFID) provides effective and efficient traceability (MONTANARI, 2008; RUIZ-GARCIA et al., 2007; RUIZ-GARCIA; LUNADEI, 2010) as well as the integration of tracking technologies and the internet of things (LUO et al., 2016).

IT deployment is more common among 3PL providers that coordinate a broad range of activities for their customers (WANKE, 2012). IT practices include the use of networked sensor technologies and radio-frequency systems (SHARMA; PAI, 2015). The Internet is a tool that helps companies discover new opportunities and provides a competitive advantage (LEE; PALEKAR; QUALLS, 2011). Radiofrequency technology provides greater visibility of chain operations, thereby increasing processing applications and reducing delivery times (RUIZ-GARCIA; LUNADEI, 2010).

Enterprise resource planning (ERP) systems provide reliable logistical information for 3PL providers' planning of transport resources and storage enabling improvements in operational performance (CHOU; CHANG, 2008).

Standardization is another factor that affects performance and contributes to improvements in supply chain efficiency (JOSHI; BANWET; SHANKAR, 2009). Certification processes, such as those developed by the International Organization for Standardization (ISO), enable service levels to be raised through the structuring and implementation of standardized procedures (WANKE, 2012). Specifically, 3PL providers of refrigeration services face a scenario that requires a highly precise level of process control (PENTEADO, 2015). In this regard, some studies have used DEA to address the SE of 3PL providers (HAMDAN; ROGERS, 2008; MIN; DEMOND; JOO, 2013; MIN; JONG JOO, 2006; MIN; JOO, 2009; WANKE, 2012; WANKE; AFFONSO, 2011; ZHOU et al., 2008). However, there is a lack of research about 3PL providers of refrigeration services.

3. RESEARCH METHODS

This current study is quantitative, exploratory, and descriptive. It assesses the scale efficiency of Brazilian 3PL providers of refrigeration services. In so doing, the study explores how this sector of the Brazilian economy is composed, examines the main variables of the companies in the sector based on its growth, describes the determinants of efficiency, and considers the relationship between the relevant variables. The data used in this research was collected are from special editions of the Tecnologística Review that are devoted to the characteristics of the Brazilian 3PL market for refrigeration services. The special editions used in this research were published on June or July every year between 2008 and 2015. This period was selected because it includes technological variables that are widely used in the literature. Such an approach also significantly differs from the work of Wanke (2012) and Wanke and Affonso (2011). This research applies a two-stage DEA model: DEA efficiency in stage one was followed by a Tobit regression analysis using unbalanced panel data in stage two. Wanke (2012) used factor analysis for data reduction based on observed variables before Tobit regression. In this research, all contextual variables were used in order to indicate specifically variables that impact in scale efficiency. Furthermore, we used a t-test to evaluate the difference between the average gross revenues of the 3PL providers for each variable, which has a significant effect on the SE.

3.1 Data Envelopment Analysis

DEA consists of a set of techniques and mathematical programming models that assess the relative efficiency of production units (decision-making units or DMUs). It considers multiple inputs that are used and the outputs that are produced. The use of benchmarking, via DEA seeks to identify performance measures for different operating units, measuring internal performance levels, as well as competitors. It also intends to compare performance levels and identify advantages and disadvantages of operating models. Benchmarking is a management tools to implement the best practices found in similar industries or even in different industries in order to improve the performance of an organization (MIN; DEMOND; JOO, 2013).

Modern benchmarking analyses increasingly use best practice or frontier analysis methods. In the literature it is common to distinguish parametric and nonparametric approaches (BOGETOFT; OTTO, 2011). Parametric models are characterized by being defined a priori except for a finite set of unknown parameters that are estimated from data. Nonparametric models are characterized by being much less restricted a priori. Another relevant distinction is between deterministic and stochastic models (BOGETOFT; OTTO, 2011; COOPER; SEIFORD; ZHU, 2011). In stochastic models, one make a priori allowance for the fact that the individual observations may be somewhat affected by random noise, and tries to identify the underlying mean structure stripped from the impact of the random elements. In deterministic models, the possible noise is suppressed and any variation in data is considered to contain significant information about the efficiency of the firms and the shape of the technology. The two approaches that are more utilized in the literature are the non-parametric, deterministic approach called Data Envelopment Analysis (DEA) and the parametric, stochastic approach called Stochastic Frontier Analysis (SFA). DEA is advantageous by having a very flexible production structure while SFA is advantageous by allowing a better separation of noise and inefficiency. In this research, DEA was chosen due to its advantage of does not requiring the definition a priori of relative weights for inputs and outputs (COOPER; SEIFORD; ZHU, 2011).

There are two classic DEA models: the Charnes, Cooper, Rhodes (CCR) model (also known as constant returns to scale (CRS), and the model proposed by and the Banker, Charnes, Cooper (BCC) also known as variable returns to scale (VRS) proposed by Banker et al., (1984). The CCR model, which reflects "pure efficiencies," uses constant returns to scale; namely, any variation of input produces a variation of intensity across outputs. The following DEA CCR model is the basic model with envelope orientation inputs:

$$\begin{aligned} &\theta^* = \min \theta \\ &\text{subject to} \\ &\textstyle\sum_{j=1}^{n} \lambda_j x_{ij} \leq x_{i0}\ i = 1, 2, \ldots, m \\ &\textstyle\sum_{j=1}^{n} \lambda_j y_{rj} \leq \theta y_{r0}\ r = 1, 2, \ldots, s \\ &\lambda_j \geq 0\ j = 1, 2, \ldots, n\ , \end{aligned} \tag{1}$$

given a set of observations, n, for the DMUs. Each observation, DMU_j (j = 1, 2, ..., n), uses m inputs, x_{ij} (i = 1, 2, ..., m), to produce s outputs, y_{rj} (r = 1, 2, ..., s). DMU_0 is one of the DMUs under evaluation, and x_{i0} and y_{r0} are i inputs and r outputs for DMU_0 respectively. λ_j is the unknown weight, where j = 1, 2, ..., n for the DMUs ranked against each other. If restriction $\sum_{j=1}^{n} \lambda_j = 1$ is added to the equation, the BCC model is obtained (BANKER; CHARNES; COOPER, 1984). The CCR and BCC models identify the scores of relative efficiency, θ^*, for the analyzed DMU. These scores are constructed by measuring how far the usefulness of a DMU is from the border. A DMU is efficient if it has a score of 1, while a lower score indicates inefficiency.

A DMU's inefficiency can result from improper operation of the DMU itself or an improper operational scale. The scale model of efficiency (EE), calculated by the ratio $EE = \frac{\theta_{CCR}}{\theta_{BCC}}$, expresses how close one DMU is to the ideal scale size. The larger the scale of efficiency, the closer a company is to its maximum scale. When a DMU's score is 1, the CCR and BCC models suggest that the DMU is operating in the optimal size range. However, if $0 < EE < 1$, there is an inefficiency scale that is determined by the sum of the BCC model's weights. If this sum is equal to 1, the CRS law prevails; but if the sum is less than or greater than 1, increasing returns or decreasing returns to scale apply respectively (BOGETOFT; OTTO, 2011).

This current study, similar to those of Ross and Droge (2004) and Wanke (2012), seeks to determine how close each 3PL provider is to its corresponding, optimally productive scale size. The result is the consequence of a 3PL provider's coordination processes in the supply chain; namely, those related to the management of information flows, inventory control, and design capabilities. Ross and Droge (2004) state that large-scale distribution systems and various coordination processes lead to different patterns of resource allocation among activities and may improve the flexibility that is needed to fit the scale of operations. Thus, SE results indicate opportunities for downsizing (decreasing returns to scale) or consolidation operations (increasing returns to scale) (WANKE, 2012; WANKE; AFFONSO, 2011). Consequently, this study seeks to assess the main determinants of the SE of 3PL providers of refrigeration services, determining whether such determinants provide a more rational allocation of resources (inputs) to demand (outputs).

Many studies combine the scores generated by DEA with multivariate data analysis in two stages to encompass exogenous factors that can affect DMUs' performance(COOPER; SEIFORD; TONE, 2007; SIMAR; WILSON, 2007).

Turner et al. (2004) advocate the use of Tobit regression in DEA scores. In general, the Tobit regression model is similar to the ordinary least squares (OLS) model; however, the former assumes truncated normal distribution in normal distribution substitution in addition to employing estimation methods of maximum likelihood (TURNER; WINDLE; DRESNER, 2004). Thus, the dependent variable (SE) is continuous but truncated by 1. Consequently, the OLS approach to 3PL providers is inappropriate because it can produce inconsistent estimators. The procedures based on DEA using Tobit regression in the second stage perform as well as parametric methods in order to estimate the impact of contextual variables on productivity (BANKER; NATARAJAN, 2008).

This study uses Tobit regression applied to unbalanced panel data for the Brazilian 3PL providers of refrigeration services for 2008–2015. In sum, the panel data have spatial and temporal dimensions (GUJARATI, 2006). This study's model exploits modifications of the variables over time and between different cross-sectional areas. The use of panel data provides heterogeneity of individuals, a higher level of information regarding the explanatory variables, less collinearity, and a greater degree of freedom for the model. Further, it is possible to use a larger number of observations in the analysis.

3.2 Analytical Model

In the first stage of this study, DEA, CCR, and BCC models with R software were used for each of the years from 2008 to 2015. Specifically, the incomplete panel data of Brazilian 3PL cold chain providers contain 43 individuals, totaling 100 observations distributed over the relevant years.

The DEA models used three inputs and two outputs that were common to all 3PL providers of refrigeration services. The inputs were the number of employees, the total warehouse area, and the total warehouses (owned and outsourced). The outputs were represented by variables that were selected to reflect financial and operational aspects; thus, the outputs were gross revenues and number of customers. The gross revenues from 3PL providers of refrigeration services reflect the sale of services. The number of clients reflects operational complexity. An extensive portfolio of clients indicates a good market image and the managerial ability of different logistics services (WANKE, 2012; WANKE; AFFONSO, 2011).

A large number of inputs and outputs compared with the number of DMUs decreases the discriminatory power of the DEA model. In this regard, the literature has suggested various techniques to limit the number of variables (COOK; TONE; ZHU, 2014). For example, Banker et al. (1984) show that the number of DMUs should be at least three times the combined number of inputs and outputs. Golany and Roll (1989) suggest relying upon the judgment of experts to indicate the most relevant variables for the DEA model. Wagner and Shimshak (2007) demonstrate the application of DEA to reduced models in order to classify the effect of variables on efficiency scores. Lewin et al. (1982) and Wanke (2012) propose regression analysis to indicate highly correlated redundant variables. Given that the correlations between the sets are relatively low, all inputs and outputs were retained for the analysis. It is also worths noting that the number of DMU observations is greater than three times the sum of the inputs and outputs ($43 \geq 3\ (3 + 2)$).

4. RESULTS

Table 1 presents the descriptive statistics of the scores of the CCR, BCC, and SE models for 2008–2015. The CCR model produces lower efficiency estimates than the BCC model, with mean values of 0.468 and 0.696 respectively. In addition, the CCR model identifies 24 efficient 3PL providers of refrigeration services compared with 52 in the BCC model. This result is unsurprising because the BCC model reports the imposition of technology with CRS and enables the production set to present VRS.

Table 1 - Descriptive statistics of DEA scores by year

Score	Year	2008	2009	2010	2011	2012	2013	2014	2015	All
CCR	Average	0.325	0.372	0.653	0.677	0.588	0.600	0.499	0.191	0.468
	Minimum	0.015	0.056	0.050	0.184	0.179	0.119	0.027	0.010	0.010
	Maximum	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
	Standard deviation	0.421	0.344	0.416	0.366	0.308	0.357	0.369	0.311	0.381
	Coefficient of variation	1.293	0.925	0.637	0.541	0.523	0.595	0.739	1.629	0.816
	Total efficient DMUs	2	1	4	4	3	4	4	2	24
	% of efficient DMUs	25	9	44	50	25	31	19	11	27
BCC	Average	0.714	0.634	0.737	0.761	0.823	0.744	0.683	0.574	0.696
	Minimum	0.242	0.163	0.150	0.197	0.287	0.155	0.079	0.044	0.044
	Maximum	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
	Standard deviation	0.318	0.364	0.396	0.350	0.280	0.317	0.377	0.416	0.357
	Coefficient of variation	0.446	0.574	0.538	0.461	0.341	0.425	0.551	0.726	0.512
	Total efficient DMUs	4	5	6	5	7	7	10	8	52
	% of efficient DMUs	50	45	67	63	58	54	48	44	54
SE	Average	0.427	0.569	0.843	0.902	0.732	0.790	0.728	0.382	0.657
	Minimum	0.015	0.075	0.335	0.371	0.179	0.207	0.194	0.027	0.015
	Maximum	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
	Standard deviation	0.425	0.320	0.273	0.217	0.263	0.265	0.294	0.349	0.344
	Coefficient of variation	0.995	0.563	0.324	0.241	0.359	0.336	0.404	0.914	0.523
	Total efficient DMUs	2	1	4	4	3	4	4	2	24
	% of efficient DMUs	25	9	44	50	25	31	19	11	27
	Total DMUs	8	11	9	8	12	13	21	18	100
	Total DMUs—CRS	2	1	4	4	3	4	4	2	24
	Total DMUs VRS—Increasing	6	10	3	4	5	4	17	15	64
	Total DMUs VRS—Decreasing	0	0	2	0	4	5	0	1	12

In the BCC model, many DMUs are technically effective (with an average of 54% over eight years). In other words, they have a score of 1 in this model. However, few 3PL providers of refrigeration services (19% and 11% in 2014 and 2015 respectively) operate at a level close to the most productive scale size (the CCR model captures both the technical efficiency and scale). The analysis of the SE model demonstrates that most 3PL providers of refrigeration services face increasing returns to scale (64%), followed by those with constant returns (24%) and by those that provide services with decreasing scale returns (12%).

The second stage identifies the determinants of SE among 3PL providers in the Brazilian cold chain by using the main features and services offered by 3PL providers that are identified in Tecnologística Review. Table 2 shows 22 binary control variables; namely, the dummy feature scale used in the research. These variables have the value of 1 if a characteristic is present; otherwise, the value is 0.

Table 2 - Variables considered in the analysis

Certification	Inventory and storage service	Transportation services	Tax-related services	Technologies employed
ISO certification	*Stock control* *Packaging* *Kit assembly* *Intermodal management* *Reverse logistics*	*Cross-docking* *Distribution* *Door-to-door* *Transfers*	*Customs clearance* *Tax support*	*WMS (Warehouse Management System)* *TMS (Transportation Management System)* *ERP (Enterprise Resource Planning)* *Internet queries* *Bar code* *Radio frequency* *In-house satellite tracking* *In-house radio tracking* *In-house cell phone tracking* *In-house routing*

Tobit regression was then applied to the unbalanced panel data using Stata econometric software (see Table 3). The range 0.05–0.10 was used as the acceptable level of significance, as is customary in exploratory research studies on logistics (MENTZER; FLINT, 1997; WANKE, 2012).

It is worth mentioning that the analyses in this section deal with SE; in other words, the analyses verify whether a DMU performs its operations within a suitable scale. DMUs may operate with constant, increasing, or decreasing returns. Production with constant returns is known as optimal scale.

The results presented in Table 3 demonstrate that stock control has a significant effect on the SE of 3PL providers of refrigeration services. In this regard, Wanke (2012) proposes that inventory control provides more effective integration of customer product flow with the transport resources and storage of 3PL providers, all of which are necessary for movement. In addition, kit assembly negatively impacts the SE of 3PL providers of refrigeration services. Brazil is one of the most expensive countries in respect of taxes. Despite that, there is no specific tax legislation for logistics in Brazil. Thus, companies seek the most viable fiscal alternative to meet their clients properly paying taxes without fiscal risks. The appropriate tax planning reduces the tax burden on companies related to the most important activities of the logistics sector: storage, transportation, and location. Thus, the changes in project logistics and operations allow deriving tax benefits. Such alterations impact directly on the scale of production of logistic operators. An example of kit assembly services in the context of refrigerated services are kits for the promotional campaigns, small product sizes, and family size package. Products susceptible to seasonality in sales, such as yogurt, require a trained and acclimatized area team for optimal handling of products without undergoing thermal variations or loss of property.

Moreover, kit assembly is an operation that generates other activities, which implies significant organization. The shortage of specialized labor, especially for kit assembly services, reduces warehouse productivity. Consequently, this study used a t-test to evaluate the difference between the average gross revenues of the 3PL providers. Those that provide a kit assembly service have an average income of R$134 million, which is significantly lower ($t = -3.295$, $p < 0.000$) than the average income of R$473.37 million of those providers that do not have such a service.

Table 3 - Tobit regression results

Variable	Tobit regression					
	Coefficients	Standard error	z	P > [z]	[Confidence interval 95%]	
ISO certification	-0.0512307	0.086585	-0.59	0.554	-0.2209343	0.1184728
Stock control	0.4446715	0.2154185	2.06	0.039	0.022459	0.8668839
Packaging	-0.1372625	0.1098122	-1.25	0.211	-0.3524905	0.0779655
Kit assembly	-0.2394895	0.12864	-1.86	0.063	-0.4916192	0.0126402
Intermodal management	-0.0417522	0.0876286	-0.48	0.634	-0.2135011	0.1299967
Customs clearance	0.0331211	0.0966084	0.34	0.732	-0.1562279	0.22247
Reverse logistics	-0.0947534	0.1197074	-0.79	0.429	-0.3293756	0.1398688
Tax support	0.2606973	0.1396884	1.87	0.062	-0.0130869	0.5344816
Cross-docking	0.166259	0.1474723	1.13	0.26	-0.1227815	0.4552995
Distribution	0.1604759	0.1228308	1.31	0.191	-0.080268	0.4012198
Door-to-door	-0.4197659	0.12505	-3.36	0.001	-0.6648594	-0.1746725
Transfers	0.2456666	0.1346593	1.82	0.068	-0.0182607	0.509594
WMS	0.0296093	0.1626907	0.18	0.856	-0.2892585	0.3484772
TMS	-0.0518307	0.1225605	-0.42	0.672	-0.2920448	0.1883835
ERP	0.311504	0.1213533	2.57	0.01	0.0736559	0.5493521
Internet queries	0.2473869	0.1455183	1.7	0.089	-0.0378237	0.5325975
Bar code	-0.2574425	0.1645321	-1.56	0.118	-0.5799195	0.0650344
Radio frequency	-0.1039954	0.1081876	-0.96	0.336	-0.3160391	0.1080483
In-house satellite tracking	-0.4358991	0.1634351	-2.67	0.008	-0.7562261	-0.1155722
In-house radio tracking	0.2720855	0.1500058	1.81	0.07	-0.0219205	0.5660916
In-house cell phone tracking	-0.0002056	0.1594135	0	0.999	-0.3126504	0.3122391
In-house routing	0.3999725	0.1932613	2.07	0.038	0.0211873	0.7787577
Sigma (u)	0	0.0747498	0	1	-0.1465068	0.1465068
Sigma (e)	0.3367788	0.0283317	11.89	0	0.2812497	0.392308

Note: Log likelihood = -41.882274, Wald chi^2 = 390.41, Prob > chi^2 = 0.0000, number of observations= 100, unbalanced panel = 43 individuals

Tax support promotes greater SE among 3PL providers. The complexity of the Brazilian tax system explains this circumstance. Tax adjustments may enable 3PL providers to obtain new business, simplify procedures, and legally support their operations. Such support is essential for the evaluation of the best tax scenario for each logistics operation and helps commercial negotiations with shippers. In addition, the 3PL providers that offer a tax support service have an average income (R$251.17) that is significantly higher (t=1.517, p<0.021) compared with those that do not offer such a service (R$91.18).

The ability to offer transfers among units promotes greater SE for 3PL providers of refrigeration services. This result possibly originates from the scale resizing provided by the exchange of products between factories and distribution centers, and an optimized occupancy rate of vehicles that are used by 3PL providers. Furthermore, many shippers outsource this type of operation in order to reduce costs because they do not have adequate cost control when they use their own transfer service.

Door-to-door services decrease the SE of 3PL providers. This service refers to all logistics processes (contract freight rate, insurance, customs clearance, and domestic transport) and culminates in the delivery of a product to the desired location. The service requires 3PL providers to have large capacities and to be flexible, which may explain the service's impact. The t-test that was performed to compare the differences among average gross incomes shows that those 3PL providers that offer the service have an average income (R$154.62) significantly lower (t=-1.728, p<0.000) compared with the others (R$316.15). Such a service has high, complex costs. In addition, shippers that have the service must engage in arduous negotiations in order to reduce their prices in a predatory competitive environment.

The operations of 3PL providers of refrigeration services demand precise controls. IT and control equipment enables companies to rationalize management and reduce costs by adopting processes, systems, and tools that contribute to the maximization of operations and that consequently reduce costs. The results show the impact of the following items: ERP, Internet queries, in-house radio tracking, in-house routing, and in-house satellite tracking.

ERP enables the integration of information on demand, thereby improving the reliability of data for decision-making regarding transportation and storage, and ensuring better operational performance. Internet queries and in-house radio tracking provide a better match between resources and demands, thereby reducing the time involved with the sending and receiving cycle, increasing shipping accuracy, and decreasing response time variability (WANKE, 2012). The use of in-house routing is essential because the current dynamic of urban distribution, which aims to provide the right product at the right time, is a process that is increasingly complex and requires optimal solutions. However, in-house satellite tracking has a negative impact on the efficiency of 3PL providers because it requires significant investment for implementation. Nonetheless, in-house satellite tracking provides virtually global coverage for traceability. The technology can also be used in areas that are not covered by telephone companies. Given the potential coverage, though, a 3PL provider of a refrigeration service with a local or regional operation may have excess capacity and traceability. Thus, other technologies such as radio coverage may be more efficient because they require less cost and cover a broad area without excess capacity. It is noteworthy that the average revenue of 3PL providers that have in-house satellite tracking (R$318.64) is significantly higher ($t=2.292$, $p<0.003$) than the average income of those without it (R$115.05). Thus, although the variable, in-house satellite tracking, has a negative impact on 3PL providers' SE, it significantly impacts gross revenues.

Finally, it is worth noting that the contextual variables of in-house radio tracking, ERP, Internet queries, stock control, and kit assembly found in this present study are aligned with other studies of the 3PL industry (WANKE; AFFONSO, 2011).

4.1 Managerial Implications

The South, Southeast, and West Central Brazilian regions are the origin of large volumes of refrigerated cargo that is distributed to the rest of the country and abroad (BURSZTEIN, 2014). In this sense, increased collaboration can strengthen comprehensive strategic actions in a highly competitive market. However, partnership arrangements among Brazilian 3PL providers are not well established. Thus, owner-run facilities are still the main infrastructure model of a 3PL provider, which implies high costs. Regarding the outputs produced by the model, and focusing particularly on financial and operational measures, the total number of customers is understood to reflect operational complexity; namely, a greater number of customers may indicate a better reputation in the market and the ability to manage different services. Offering more customized services, however, requires more employees with different skills, full- or part-time, together with equipment and possibly facilities. Staff costs are expensive and do not enable productivity gains. Consequently, companies have made significant investments in IT in order to change this situation (BURSZTEIN, 2014).

There may be differences in SE between asset-based 3PL providers and those that were not evaluated in this study because of unavailable data classifications. Min and Joo (2006), for example, present evidence that asset-based 3PL providers underuse assets and consequently are financially inefficient. In contrast, operators that are not asset based have greater opportunities

for financial efficiency. Further, some studies make points that should be borne in mind. Hamdan and Rogers (2008) and Min et al. (2013) present an approximation of the reality in Brazil. Their results indicate that small 3PL providers that operate in niche markets and with limited services tend to achieve a better performance compared with large competitors that offer a wide range of services. These results contradict the emphasis on customized services expressed earlier because small 3PL providers do not extend their range of services nor engage in cooperation and yet they obtain better operational and financial results. This makes no sense of any proposed attempt to increase the market qualifications of small 3PL providers. However, these providers could be regarded as potential regional partners of larger 3PL companies.

Another issue worth highlighting is that the excess capacity of large 3PL providers tends to result in them underusing their resources. Zhou et al. (2008) show that greater revenue enables the better use of resources and improved operational efficiency, both of which depend upon the retention of specialized human resources. The Brazilian situation suggests an inverse position in which higher revenues and more employees are related to larger operators and lower efficiency levels. Namely, the results suggest that national operators seem to grow without suitable market planning, experience problems in finding demand for their services, and are sometimes kept in business by one or few customers (shippers). Such circumstances are insufficient to support operational costs.

Finally, the results confirm the importance of IT in logistics coordination processes and SE (WANKE, 2012; WANKE; AFFONSO, 2011). However, the results also make the point that the market is not mature enough for significant investment by 3PL providers. Investments that enable providers to offer more specialized services, such as kit assembly and door-to-door transportation, render most providers vulnerable financially compared with those providers that limit themselves to more traditional services (such as general transport and storage) and that have a local or regional scope.

5. FINAL REMARKS AND CONCLUSIONS

This study contributes to an assessment of the main SE determinants for 3PL providers of refrigeration services in Brazil. The 3PL providers with better financial and operating results are those that have implemented stock control, tax support, and product transfer between units, together with IT tools such as ERP, Internet queries, and tracking by radio and routing systems. However, specialized services such as kit assembly and door-to-door delivery have a negative impact on revenue because of the difficulty of pricing such services. The causes of this difficulty are the need to forecast the use of services, extend processes, and engage in a large number of activities.

The complexity of logistics operations and the options that must be offered place 3PL providers under pressure. This situation indicates that market power is unbalanced in favor of shippers and that shippers under-remunerate the service providers. Complex services that are offered by a 3PL provider do not result in better outcomes because, in general, such services do not meet all of a shipper's requirements. This state of affairs also makes it easier to understand the Brazilian situation in which the level of outsourcing is still relatively small. Thus, the following question arises: are there no qualified services because 3PL providers do not experience demand for specialized services at the right level, or do 3PL providers not experience demand for specialized services because they do not offer specialized services? The answer seems to lie in the first half of the question.

Nonetheless, 3PL providers of refrigeration services are under continuous pressure to increase their performance and provide specialized services at low costs. By developing an efficiency model, this study investigates the possibility of Brazilian 3PL providers achieving greater efficiency, a situation that would result in reduced costs and faster service provision. Shippers seek 3PL providers that offer a range of services. Thus, 3PL providers should follow a marketing plan that defines the terms of a niche market, including regional specifications, so as to be able to achieve the proposed optimal scale. Further, this study's results may be useful to shippers for evaluation of 3PL providers of refrigeration services.

This study theoretically contributes to the solidification of the DEA as a method of measurement and benchmarking in the literature on performance measurement. The study was based on the construction and validation of a scale to measure efficiency represented by the creation of a comparative index of scale efficiency for refrigerated logistics service providers.

It should be noted that this study is limited by its use of secondary data. Working with secondary data instead of primary data brings some limitations to this work, mainly with respect to the set of inputs and outputs used in the analysis. Nevertheless, the data set provided by Tecnologística Review allowed the development of a theoretical model that has been identified and applied to the research processes with data. The choice of the data base is justified by the difficulty in accessing data of 3PL providers of refrigeration services. Inputs, outputs, and contextual variables used in this study were collected from the special edition dedicated to the 3PL providers of refrigeration services in Tecnologística Review published annually. Data collection made by the magazine uses a robust and consistent methodology ensuring the quality and reliability of information. The survey is conducted annually since 2000. Furthermore, conducting a secondary analysis of existing data saved the time and resources needed to collect primary data. Thus, there is scope for future research to develop a primary data survey in order to preselect the variables, and for another study to consider the issues raised here from the perspective of shippers.

REFERENCES

ARAMYAN, L. H. et al. Performance measurement in agri-food supply chains: a case study. **Supply Chain Management: An International Journal**, v. 12, n. 4, p. 304–315, 2007.

BANKER, R. D. Maximum Likelihood, Consistency and Data Envelopment Analysis: A Statistical Foundation. **Management Science**, v. 39, n. 9, p. 1265–1273, 1993.

BANKER, R. D.; CHARNES, A.; COOPER, W. W. Some Models for Estimating Technical and Scale Inefficiencies in Data Envelopment Analysis. **Management Science**, v. 30, n. 9, p. 1078–1092, 1984.

BANKER, R. D.; NATARAJAN, R. Evaluating Contextual Variables Affecting Productivity Using Data Envelopment Analysis. **Operations Research**, v. 56, n. 1, p. 48–58, 2008.

BOGATAJ, M.; BOGATAJ, L.; VODOPIVEC, R. Stability of perishable goods in cold logistic chains. **International Journal of Production Economics**, v. 93–94, p. 345–356, 2005.

BOGETOFT, P.; OTTO, L. **Benchmarking with DEA, SFA, and R**. New York, NY: Springer New York, 2011.

BURSZTEIN, V. De ponta a ponta. **Revista Tecnologística**, v. 20, n. 225, p. 66–72, 2014.

CHOU, S.-W.; CHANG, Y.-C. The implementation factors that influence the ERP (Enterprise

Resource Planning) benefits. **Decision Support Systems**, v. 46, n. 1, p. 149–157, 2008.

COOK, W. D.; TONE, K.; ZHU, J. Data envelopment analysis: Prior to choosing a model. **Omega**, v. 44, p. 1–4, 2014.

COOPER, W. W.; SEIFORD, L. M.; TONE, K. **Data Envelopment Analysis**. 2. ed. Boston, MA: Springer US, 2007.

COOPER, W. W.; SEIFORD, L. M.; ZHU, J. **Handbook on Data Envelopment Analysis**. 2. ed. Boston, MA: Springer US, 2011. v. 164

FLEURY, P. F.; RIBEIRO, A. F. M. A indústria de provedores de serviços logísticos no Brasil. In: FIGUEIREDO, K. F.; FLEURY, P. F. .; WANKE, P. F. (Eds.). . **Logística e gerenciamento da cadeia de suprimentos: planejamento do fluxo e dos recursos**. São Paulo: Atlas, 2003. p. 302–312.

GOLANY, B.; ROLL, Y. An application procedure for DEA. **Omega**, v. 17, n. 3, p. 237–250, 1989.

GRANT, P. Cold Snap: Developers Pour Money Into Cold Storage in China - WSJ. **Wall Street Journal**, 2017.

GUJARATI, D. N. **Econometria básica**. 3. ed. Rio de Janeiro: Elsevier, 2006.

HAMDAN, A.; ROGERS, K. J. Evaluating the efficiency of 3PL logistics operations. **International Journal of Production Economics**, v. 113, n. 1, p. 235–244, 2008.

HUANG, C.; XIE, R. Development and Countermeasure of Food Cold Chain Logistics in China. **Storage, Transportation & Preservation of Commodities**, v. 29, n. 4, p. 37–39, 2007.

JOSHI, R.; BANWET, D. K.; SHANKAR, R. Indian cold chain: modeling the inhibitors. **British Food Journal**, v. 111, n. 11, p. 1260–1283, Oct. 2009.

LARGE, R. O.; KRAMER, N.; HARTMANN, R. K. Customer-specific adaptation by providers and their perception of 3PL-relationship success. **International Journal of Physical Distribution & Logistics Management**, v. 41, p. 822–838, 2011.

LEE, J.; PALEKAR, U. S.; QUALLS, W. Supply chain efficiency and security: coordination for collaborative investment in technology. **European Journal of Operational Research**, v. 210, n. 3, p. 568–578, 2011.

LEWIN, A. Y.; MOREY, R. C.; COOK, T. J. Evaluating the administrative efficiency of courts. **Omega**, v. 10, n. 4, p. 401–411, 1982.

LO, C. K. Y.; YEUNG, A. C. L.; CHENG, T. C. E. ISO 9000 and supply chain efficiency: Empirical evidence on inventory and account receivable days. **International Journal of Production Economics**, v. 118, n. 2, p. 367–374, 2009.

LUO, H. et al. An intelligent tracking system based on internet of things for the cold chain. **Internet Research**, v. 26, n. 2, p. 435–445, 4 Apr. 2016.

MALONI, M. J.; CARTER, C. R. Opportunities for research in third-party logistics. **Transportation Journal**, v. 45, n. 2, p. 23–38, 2006.

MARASCO, A. Third-party logistics: A literature review. **International Journal of Production Economics**, v. 113, n. 1, p. 127–147, 2008.

MENTZER, J. T.; FLINT, D. J. Validity in logistics research. **Journal of Business Logistics**, v. 18, n. 1, p. 199, 1997.

MIN, H.; DEMOND, S.; JOO, S.-J. Evaluating the comparative managerial efficiency of leading third party logistics providers in North America. **Benchmarking: An International Journal**, v. 20, n. 1, p. 62–78, 2013.

MIN, H.; JONG JOO, S. Benchmarking the operational efficiency of third party logistics providers using data envelopment analysis. **Supply Chain Management: An International Journal**, v. 11, n. 3, p. 259–265, 2006.

MIN, H.; JOO, S. Benchmarking third-party logistics providers using data envelopment analysis: an update. **Benchmarking: An International Journal**, v. 16, n. 5, p. 572–587, 28 Aug. 2009.

MONTANARI, R. Cold chain tracking: a managerial perspective. **Trends in Food Science & Technology**, v. 19, n. 8, p. 425–431, 2008.

PENTEADO, F. Tudo muito sob controle. **Revista Tecnologística**, v. 21, n. 237, p. 48–54, 2015.

ROSS, A. D.; DROGE, C. An analysis of operations efficiency in large-scale distribution systems. **Journal of Operations Management**, v. 21, n. 6, p. 673–688, 2004.

RUIZ-GARCIA, L. et al. Review. Monitoring the intermodal, refrigerated transport of fruit using sensor networks. **Spanish Journal of Agricultural Research**, v. 5, n. 2, p. 142–156, 2007.

RUIZ-GARCIA, L.; LUNADEI, L. Sustainable Radio Frequency Identification Solutions. In: TURCU, C. (Ed.). . **Sustainable Radio Frequency Identification Solutions**. Croatia: InTech, 2010. p. 37–50.

SAHAY, B. S.; MOHAN, R. 3PL practices: an Indian perspective. **International Journal of Physical Distribution & Logistics Management**, v. 36, n. 9, p. 666–689, 2006.

SAHIN, E. et al. Ensuring supply chain safety through time temperature integrators. **The International Journal of Logistics Management**, v. 18, n. 1, p. 102–124, 2007.

SHABANI, A.; SAEN, R. F.; TORABIPOUR, S. M. R. A new benchmarking approach in Cold Chain. **Applied Mathematical Modelling**, v. 36, n. 1, p. 212–224, 2012.

SHABANI, A.; TORABIPOUR, S. M. R.; SAEN, R. F. Container selection in the presence of partial dual-role factors. **International Journal of Physical Distribution & Logistics Management**, v. 41, n. 10, p. 991–1008, 2011.

SHARMA, S.; PAI, S. S. Analysis of operating effectiveness of a cold chain model using Bayesian networks. **Business Process Management Journal**, v. 21, n. 4, p. 722–742, 2015.

SIMAR, L.; WILSON, P. W. Estimation and inference in two-stage, semi-parametric models of production processes. **Journal of Econometrics**, v. 136, n. 1, p. 31–64, 2007.

SUN, C.-H. et al. Anti-counterfeit code for aquatic product identification for traceability and supervision in China. **Food Control**, v. 37, p. 126–134, 2014.

TURNER, H.; WINDLE, R.; DRESNER, M. North American containerport productivity: 1984–1997. **Transportation Research Part E: Logistics and Transportation Review**, v. 40, n. 4, p. 339–356, 2004.

WAGNER, J. M.; SHIMSHAK, D. G. Stepwise selection of variables in data envelopment analysis: Procedures and managerial perspectives. **European Journal of Operational Research**, v. 180, n. 1, p. 57–67, 2007.

WANG, Y. et al. Developing an ontology-based cold chain logistics monitoring and decision system. **Journal of Sensors**, v. 2015, p. 1–8, 2015.

WANKE, P.; ARKADER, R.; FERNANDA HIJJAR, M. Logistics sophistication, manufacturing segments and the choice of logistics providers. **International Journal of Operations & Production Management**, v. 27, n. 5, p. 542–559, 2007.

WANKE, P. F. Determinants of scale efficiency in the Brazilian 3PL industry: a 10-year analysis. **International Journal of Production Research**, v. 50, n. 9, p. 2423–2438, May 2012.

WANKE, P. F.; AFFONSO, C. R. Determinantes da eficiência de escala no setor brasileiro de operadores logísticos. **Produção**, v. 21, n. 1, p. 53–63, 2011.

WILSON, T. P.; CLARKE, W. R. Food safety and traceability in the agricultural supply chain: using the Internet to deliver traceability. **Supply Chain Management: An International Journal**, v. 3, n. 3, p. 127–133, 1998.

XIAO, X. et al. Applying CS and WSN methods for improving efficiency of frozen and chilled aquatic products monitoring system in cold chain logistics. **Food Control**, v. 60, p. 656–666, 2016.

ZACHARIA, Z. G.; SANDERS, N. R.; NIX, N. W. The emerging role of the third-party logistics provider (3PL) as an orchestrator. **Journal of Business Logistics**, v. 32, n. 1, p. 40–54, 2011.

ZHANG. **Cold Chain Management**. United Kingdom: Cranfield Centre for Logistics & Supply Chain Management, 2007.

ZHOU, G. et al. Evaluating the comparative efficiency of Chinese third-party logistics providers using data envelopment analysis. **International Journal of Physical Distribution & Logistics Management**, v. 38, n. 4, p. 262–279, 2008.

ZHOU, J.; YAN, Z.; WANG, Y. Improving quality and safety of aquatic products: A case study of self-inspection behavior from export-oriented aquatic enterprises in Zhejiang Province, China. **Food Control**, v. 33, n. 2, p. 528–535, 2013.