

**B2C e-commerce for home appliances in the Brazilian market: a cost efficiency
investigation through a DEA-OCT model**

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Resumo

O e-commerce B2C representa uma inovação para os modelos de negócios varejistas tradicionais e um desafio para suas gestões de estoque e logística. No Brasil, um fato relevante foi a valorização das ações da varejista de eletrodomésticos, Magazine Luiza. Esses papéis valorizaram 7.608 % entre 2016 e 2018, e a empresa atribui a causa desse desempenho à implementação bem-sucedida do seu plano estratégico de inovação em cadeia de suprimentos, gestão de estoque e logística para e-commerce. O presente trabalho fez um levantamento descritivo, por meio de relatórios oficiais e notícias da mídia, do mercado onde Magazine Luiza está inserida. Foram identificados 7 competidores de capital aberto (B2W, Americanas.com, Via Varejo, Mercado Livre, Carrefour, Walmart e Amazon), sobre os quais serão mostrados um breve resumo descritivo. Este trabalho também fez uma análise da eficiência da gestão dos estoques (com base em custos) desses *players*, por meio de um modelo DEA-OCT, que combina Análise Envoltória de Dados (DEA) com Teoria do Controle Ótimo (OCT). Essa abordagem foi proposta por Alves Junior (2018) e tem por objetivo calcular a eficiência otimizada ao longo do tempo, quando o sistema possui variáveis relacionadas entre si, como é o caso do controle de estoque. Os dados foram colhidos dos demonstrativos trimestrais entre o último de 2010 e o segundo de 2018 (disponíveis no software Economatica). Os resultados discutem as melhores práticas de cada *player* e apontam que, apesar da sua valorização extraordinária, Magazine Luiza não é uma referência na gestão de custos de estoque, quando comparada a seus pares: Walmart, Mercado Livre, Amazon e Carrefour.

Palavras-chave: E-commerce; Varejo; Análise Envoltória de Dados (DEA); Teoria do Controle Ótimo (OCT); Gestão de Estoque.

Abstract

B2C e-commerce represents an innovation for traditional retail business models and a challenge for their inventory and logistics management. In Brazil, a relevant fact was the valuation of the shares of the home appliance retailer, Magazine Luiza. These stocks valued 7,608% between 2016 and 2018, and the company attributes the cause of this performance to the successful implementation of its strategic plan for innovation for e-commerce, considering supply chain, inventory, and logistics management. We made a descriptive investigation, through official reports and news media, of the market where Magazine Luiza is inserted. Seven publicly traded competitors were identified (B2W, Americanas.com, Via Varejo, Mercado Livre, Carrefour, Walmart, and Amazon). A brief narrative summary about them will be presented. We also analyzed the efficiency of inventory management (cost-based) of these players, through a DEA-OCT model that combines Data Envelopment Analysis (DEA) with Theory of Optimal Control (OCT). This approach was proposed by Alves Junior (2018)

and aims to calculate the optimized efficiency over time when the system has variables related to each time period (predecessor and successor), as is the case of inventory control. The data were taken from the quarterly statements between the last of 2010 and the second of 2018 (retrieved from the Economática software). The results discuss players' best practices and point out that, despite its extraordinary stock valuation, Magazine Luiza is not a reference in the management of inventory costs when compared to its peers: Walmart, Mercado Livre, Amazon, and Carrefour.

Keywords: e-commerce; retail; data envelopment analysis (DEA); optimal control theory (OCT); inventory management.

1. Introduction

Since the 1990s, the advent of new information and communication technologies (ICT), such as the Internet, has given rise to new forms of business and new relationships between customers and suppliers (Mokhtarian, 2004).

In this context, World Trade Forum recognizes e-commerce as a propelling vehicle for economic and social development, with a strong impact on the structure of supply chains and demand (Herman, 2010).

DHL Company believes B2C (Business to Customer) e-commerce will reach \$ 1 trillion worldwide by 2020 and that, this year, 900 million people will be transnational online consumers (Ghemawat & Altamn, 2016).

In Brazil, a significant fact was the valuation of the shares of the company Magazine Luiza since January 2016 (traded under the code **MGLU3** on the Brazilian stock exchange, the B3). The average value of MGLU3 at the end of that month was R \$ 1.79. By the end of December of the same year, it was R \$ 12.86, representing a growth of 718.43%. This advance continued in the following months, in September 2018 the average value was R \$ 136, 19 (a valuation of 7,608 %), according to the data retrieved from Economática software (and corrected by inflation).

B3 classifies MGLU3 as **cyclic consumption/commerce/home appliances**. According to the official statement to shareholders (MGLU3, 2018), Magazine Luiza executives believe that their success is due to the strategic plan for innovation in the supply chain, inventory and logistics management for e-commerce. MGLU3 (2018, p.99) states: "The main competitors of the Company are: Mercado Livre, B2W, Via Varejo, Máquina de Vendas, Walmart, Carrefour, among others." It is noteworthy that the giant Amazon is not cited. Amazon entered in the Brazilian market in 2016 (EXAME, 2017) and it is worldwide studied as a reference in e-commerce and logistics innovation (Boysen, de Koster, & Weidinger, 2018; Tian, Vakharia, Tan, & Xu, 2018).

Given the presented context, we aim to draw a descriptive profile of the B2C e-commerce scenario for the Brazilian home appliance market, focusing on publicly traded companies. In addition, we seek to understand and measure the cost efficiency of the market players.

2. Literature Review

The B2C e-commerce researchers agree that logistics is a pillar for the development of e-commerce initiatives (Cullinane, 2009; Joong-Kun Cho, Ozment, & Sink, 2008; Mokhtarian, 2004; Ramanathan, George, & Ramanathan, 2014). It is cited among the factors that, if not well-managed, can cause the failure of a business in the sector (Delfmann, Albers, & Gehring, 2002). In addition, the efficiency of the distribution network is seen as one of the causes of the success of companies in the market (Joong-Kun Cho et al., 2008).

Tian et al. (2018), when strategically analyzing the e-commerce model called **marketplace**, attested that, from the perspective of efficiency, it is recommended to consider the costs related to the inventory, storage, and transport system. The authors refer to these three costs jointly, as **order-fulfillment costs**.

A marketplace is considered mandatory for all e-commerce companies, that compete in Latin America (EMARKETER, 2017). The marketplace is a virtual platform for retailers, which can operate in three modes: (i) reselling: the retailer buys all of the suppliers' products and resells them through the marketplace platform, controlling the final price and absorbing inventory and storage costs, since transport costs are usually paid by the final consumer; (ii) marketplace: suppliers sell their products directly to the end consumer through marketplace platform. Suppliers control the final prices, absorb inventory and storage costs, and pay fees to the retailer for use of the marketplace. In this way, suppliers define the price and absorb the costs of inventory and storage; (iii) hybrid: the retailer buys and resells some products and allows suppliers to also directly sell other products in the same marketplace (Tian et al., 2018).

The marketplace may be responsible for a significant portion of a company's income, or even for its totality, such as Mercado Livre, which adopts the marketplace as its exclusive sales mode (MELI, 2018). According to Tian et al. (2018), Amazon's marketplace accounted for 45% of the sold units in 2015. Amazon adopts the hybrid model and it does not seem to want to migrate to the pure marketplace. In May 2016, reselling mode represented 3.5% of the offered products in the Amazon marketplace.

Tian et al. (2018) concluded that when order-fulfillment costs are high and competition between suppliers is intense, the retailer prefers pure reselling mode. When order-fulfillment

costs are low and competition between suppliers is also not intense (e.g., fine art artifacts), the pure marketplace mode is the preferred choice. The hybrid mode prevails when both the costs and the competitive intensity are moderate.

Tian et al. (2018) gave no consideration to the impact of efficiency on the internal management of order-fulfillment costs. Transport costs are outside the scope of a conventional research because it is usually sponsored by the end customer. It is impracticable to separate warehouse costs from inventory costs through public financial statements. Readers interested in the state of the art for e-commerce warehouse should consult (Boysen et al., 2018). In this regard, we chose to investigate the efficiency of players' inventory costs management because of the recognized impact of e-commerce on the inventory and because of the practical feasibility of this mode of research (access to information).

Alves Junior (2018) developed many integrated models of OCT (Optimal Control Theory) and DEA (Data Envelopment Analysis). These models aimed to calculate the optimized efficiency over time, when the system has variables related to each other, as is the case of inventory control. That is, the stock of a period t is a result of the stock of the previous period ($t-1$), reduced the demand of t . Additionally, the proposal of Alves Junior (2018) extends the variational model, also analyzing production and demand.

The OCT part of the model obtains the dynamically optimal storage functions, while the DEA part measures the relative efficiencies of the analyzed units. In the DEA literature, these units are called DMU (Decision Making Units). Alves Junior (2018) applied a model to 647 of several sectors in South and North America, each company represents a DMU.

In Brazil, Mercado Livre and B2W are the players that adopt pure marketplace mode (BTOW3, 2018; MELI, 2018). The others adopt the hybrid mode (AMZN, 2018; CRFB3, 2018; MGLU3, 2018; VVAR4, 2018; WMT, 2018), except Americanas.com, which uses reselling mode through the B2W marketplace (LAME4, 2018).

The companies Magazine Luiza, Americanas.com and B2W were part of the sample of Alves Junior (2018). The three were inefficient in considering the final rank for the period from 2010 to 2016, though Magazine Luiza had some efficiency quarters between 2013 and 2014. The DEA tool, by measuring relative efficiency among DMUs, is very sensitive to the sample selection. Therefore, it is recommended to keep in mind an overview of the entire investigated system and the main objective of the analysis for choosing the right sample, as well as testing many configurations prior to discuss and interpret the results (Cook, Tone, & Zhu, 2014).

Alves Junior (2018) investigated the retail sector as a whole, comparing several countries simultaneously, without focusing on e-commerce specifically.

In this regard, our investigation is new because it focuses on the B2C e-commerce in a developing economy (Brazil), a relevant theme which literature is scarce and, thus, far from being consolidated (Galipoglu, Kotzab, Teller, Yumurtaci Hüseyinoglu, & Pöppelbuß, 2018).

3. Narrative Summary

Máquina de Vendas is a competitor quoted in the official statement of Magazine Luiza (MGLU3, 2018), however, it was excluded from the analysis, because it is a private company. On the other hand, two companies not mentioned were added: Amazon and Americanas.com. The first one due to its worldwide relevance (EMARKETER, 2017) and the second because of its operations are closely related to those of B2W (BTOW3, 2018; LAME4, 2018).

In this way, we read the official statement from 2017 of the following companies: Magazine Luiza, Mercado Livre, B2W, Via Varejo, Walmart, Carrefour, Americanas.com, and Amazon. To write the narrative summary, our interest was in the information related to the strategies of inventory and distribution networks for attending e-commerce. In addition, if applicable, we also sought news in the general media about related events cited in the documents.

3. 1 Magazine Luiza

Magazine Luiza is a family-owned company, founded in 1957. As early as 1992, Magazine Luiza pioneered its first e-commerce model, called *Lojas Eletrônicas*. The sales were made through multimedia terminals in the shops, consisting of vendors who guided their customers, and there were no products on display or inventory. In 1996, despite being a privately held company, Magazine Luiza released its first externally audited financial statement, a requirement only for public companies. In June 2011, Magazine Luiza ended the IPO process at B3, its shares are traded under the code MGLU3 (MGLU3, 2018).

In 2017, Magazine Luiza's digital channels jointly - site, mobile apps, and marketplace - accounted for 30% of total sales and 61% growth considering the same period of 2016 as a baseline. In 2017, the company also acquired the technology startup *Donatelo*

Desenvolvimento de Software e Market Digital Ltda. (known by the name Integra Commerce), specialized in the integration and management of the relationship between suppliers and marketplaces. The main objective of the acquisition was to accelerate the execution of the development strategy of a profitable marketplace (MGLU3, 2018). In 2018, Magazine Luiza acquired the technology startup applied to logistics Logbee, which is a

platform that manages the express delivery of light products, made daily by several suppliers (MGLU3, 2018).

Magazine Luiza has a unique and integrated system of corporate services and logistics. This system consists of more than 1,500 carriers, 716 conventional physical stores (CPSs), 141 virtual stores (VSs), 10 distribution centers (DCs) and a single shared service center (SSC). According to MGLU3 (2018), since the carriers already supply the PSs, the implementation of services related to e-commerce, such as the *Retira Loja*- purchasing mode that enables the customer to withdraw the online purchased product directly in the PSs, practically does not entail incremental costs.

3. 2 Amazon Brazil

Amazon is a US transnational publicly traded e-commerce company, founded under its name in 1994. Its shares are traded on the NASDAQ stock exchange under the code AMZN (AMZN, 2018).

According to EXAME (2017), the logistics structure of Amazon in Brazil is different from other countries. Abroad, Amazon has carriers and distribution centers (DCs) that house suppliers' products, so that Amazon's customers can receive their sales in tight due time. In Brazil, Amazon uses a unique leased DC (LDC) and outsourced transportation companies. Furthermore, Amazon opened its marketplace after its major competitors had already consolidated theirs.

3. 3 Mercado Livre

Mercado Livre (or *Mercado Libre* in Spanish) is an Argentine transnational publicly traded company (incorporated in the US) that operates exclusively through marketplaces dedicated to e-commerce and online auctions. It was founded in 1999. The company's shares are sold on the stock exchange Nasdaq under the code MELI (MELI, 2018).

According to E-Commerce News, (2018a), Mercado Livre operates and owns a single CD in Brazil, the company announced a 200% expansion of the built area in 2018. According to E-Commerce News (2018b), the company announced the launch of Mercado Envio Flex, which allows marketplace suppliers to use multiple delivery modes for their sales, including walking and cycling, to enable delivery of products on the same day of purchase. Initially, this option is only available for the city of São Paulo.

3. 4 Walmart Brazil

Walmart is a US-listed transnational corporation founded under this name in 2008. As a department store, the company was founded in 1962 under the name Wal-mart. Walmart

shares are traded on the New York Stock Exchange (NYSE) under the code WMT (WMT, 2018).

Walmart launched its marketplace in Brazil in December 2017 (Reuters, 2017). Walmart Brazil has maintained two separate companies (including with distinct headquarters) for the management of sales in physical stores and for the management of e-commerce. These two companies were consolidated into a single one in 2017 (E-Commerce News, 2017).

According to Walmart Brasil (2018), the company is a benchmark for its ability to manage and innovate in its supply chain through the intensive use of information technology. In Brazil, Walmart has 21 DCs and 543 PSs. Its network covers the South, Southeast, Northeast regions and the state of Mato Grosso do Sul, in the Center-West region.

3. 5 Carrefour Brazil

Carrefour is a transnational open company of French origin. The Carrefour group was founded in 1958. Carrefour shares are traded on the Euronext stock exchange under the code CA and also on B3 under the code CRFB3 (CRFB3, 2018).

According to CRFB3 (2018), Carrefour has 373 PSs in Brazil, located in all Brazilian states and the Federal District, which are served by 17 strategically located DCs.

In Brazil, Carrefour inaugurated its first virtual store in 2010 (E-Commerce News, 2010). In 2012, the company decided to close its e-commerce operation for restructuring it (E-Commerce News, 2012). Carrefour only resumed e-commerce in 2017 with the launch of a digital platform for the sale of food products and soon after, making it possible, for the first time in Brazil, to sell food and non-food products on the same platform (E-Commerce News, 2018c).

Besides this, the company Bling (business management system) announced its integration with the Carrefour marketplace in July 2018 (E-Commerce News, 2018a). In May of the same year, the Bling company had already joined the Walmart marketplace (E-Commerce News, 2018) and in March the Amazon's (E-Commerce News, 2018b).

According to the Paulista Supermarket Association (APAS, 2010), among the innovations in the supply chain of Carrefour, we highlight the technology of stock management by voice command. According to the Brazilian Society of Retail and Consumer Affairs (SBVC, 2017), to meet online shopping, the Carrefour network inaugurated its first dark store. A dark store is a warehouse full of products, where pickers pick and order products according to online orders. It functions as a mini-distribution center for online shopping (Benedictus, 2014).

3. 6 B2W and Americanas.com

B2W is a Brazilian retail company focused on e-commerce. The company emerged in 2006, from the merger of Americanas.com (a physical and digital retail company) with Submarino (a digital retail company) (BTOW3, 2018). B2W shares are traded on B3 under the code BTOW3. The stocks of Americanas.com, the controller of B2W, are traded on B3 under the code LAME4 and LAME3. The fact that the shares are traded under more than one code means that Americanas.com does not belong to the *Novo Mercado* (NM), a differentiation for companies with high corporate governance standards (BM&F Bovespa, 2018).

B2W may share distribution infrastructure with Americanas.com and the latter uses the B2W marketplace for its online sales. The logistics strategies of B2W are described in the official statement of Americanas.com and not of B2W. LAME4 (2018) describes that Americanas.com owned 838 PSs in December 2013 and inaugurated its fourth DC in the same year. BTOW3 (2018) describes that all B2W DCs are leased, until December 2017, the company had 11 DCs and 200 own and partner operating centers dedicated to digital platform operations.

In 2013 and 2014, B2W Digital acquired the two e-commerce specialized carriers in Brazil (Click-Rodo and Direct). In 2016, it established an operational agreement with Vialog, the leading e-commerce delivery carrier in the South region. As a result of these movements, B2W Fulfillment (warehousing, distribution and customer service) was created. B2W Fulfillment is currently responsible for delivering 98% of orders from B2W Digital sites. To support the growth of marketplace vendors, in March 2017 B2W Entrega was launched, a platform that operates and controls the deliveries of suppliers using the marketplace (BTOW3, 2018).

3.7 Via Varejo

Via Varejos came from the merger between Casas Bahia and Pontofrio in 2009, promoted by the Pão de Açúcar Group, which is controlled by the Casino Group, a French holding. The stocks of Via Varejo are traded on B3 under the codes VVAR3, VVAR4, and VVAR11 (VVAR4, 2018). This means that Via Varejo does not belong to NM.

Among the company's goals are the unification of service and the integration of customer service and physical stores (VVAR4, 2018, p.173). The company is proud to have the greatest number of PSs in its segment, 975 (VVAR4, 2018, p. 70), served by 15 leased DCs (VVAR4, 2018, p. 80).

As a general rule, freight from suppliers to the distribution center is paid by suppliers and the freight from the distribution center or warehouse to stores is paid by Via Varejo. The freight

cost for deliveries to the customer is paid by Via Varejo and a service fee is charged to the customer. The transportation of products is carried out by own transporters and contracted carriers. In 2016, Via Varejo had more than 800 own vehicles destined for the company's deliveries, and the percentage of deliveries made by third parties is approximately 90% (VVAR4, 2018, p.80). Apparently, the Via Varejo is the only company in the sector that also operates with own vehicles and the reasons for this are not clear in the official statement. After several consecutive losses, the company is in a process of restructuring and selling (InfoMoney, 2018).

4. Methodology

4.1 Data Extraction

The data were retrieved from Economática software, considering the quarterly statements in dollars, since they are companies from different countries. B3 officially endowed the International Financial Reporting Standards (IFRS) in 2010. Therefore, the target period was from the last quarter of 2010 to the second quarter of 2018.

The data collected were **cost of products sold** and **inventory** for the application of the model for analysis of cost management efficiency and **net operating revenue**, for comparison and deepening of the discussion on the results. For the sake of replicability, **Table 1** shows the descriptive statistics of the variables that were effectively used in the DEA-OCT model.

Table 1 Descriptive statistics of the data used in the model DEA-OCT.

Cost of Products Sold (in dollars)					
DMU	Obs.	Average	Std. Dev.	Min.	Max.
<i>MGLU3</i>	31	1.428764E+06	6.666860E+05	4.439330E+05	2.668064E+06
<i>BTOW3</i>	31	1.124788E+06	5.721550E+05	3.377650E+05	2.272173E+06
<i>VVAR4</i>	31	3.658402E+06	1.614877E+06	9.191050E+05	8.073326E+06
<i>MELI</i>	31	1.327170E+05	1.402530E+05	1.433200E+04	6.784950E+05
<i>WMT</i>	31	2.175506E+08	1.008690E+08	7.817700E+07	3.733960E+08
<i>AMNZ</i>	31	3.875168E+07	2.468298E+07	7.608000E+06	1.119340E+08
<i>CRFB3</i>	7	7.158191E+06	3.844583E+06	3.000884E+06	1.209885E+07
<i>LAME4</i>	31	2.283949E+06	1.120504E+06	7.974170E+05	4.257513E+06
Inventory (in dollars)					
DMU	Obs.	Average	Std. Dev.	Min.	Max.
MGLU3	31	5.005630E+05	8.573100E+04	3.040910E+05	6.741970E+05
BTOW3	31	3.667580E+05	7.879100E+04	2.259430E+05	5.399580E+05
VVAR4	31	1.178526E+06	2.428750E+05	6.602140E+05	1.617426E+06
MELI	31	4.650000E+02	8.770000E+02	0.000000E+00	3.362000E+03
WMT	31	4.417378E+07	3.574849E+06	3.631800E+07	5.150100E+07
AMNZ	31	7.967839E+06	3.596657E+06	2.888000E+06	1.604700E+07
CRFB3	7	1.445998E+06	7.944300E+04	1.275482E+06	1.511186E+06

LAME4	31	9.546130E+05	1.364840E+05	7.218590E+05	1.258710E+06
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4.2 Discrete time DEA-OCT model

The discrete time model of Alves Junior (2018) minimizes production and inventory costs to calculate allocative efficiency over the period of interest. The output is demand; the input is production, and the intermediate variable is the stock. Costs are considered as the objective function. A variational constraint of the OCT is added to describe the relationship between demand, production, and stock.

The costs of products sold is CPV. Inventory costs are divided into two periods: initial (CEI) and final (CEF). CEI is between $t=0$ and $t=T-1$, i.e., the inventory of from the period before the first quarter (equal to the initial of the first quarter) until the second-to-last period (equal to the initial of the last quarter). For this reason, it is not possible to calculate the efficiency during the first and the last quarter of the retrieved data. CEF corresponds to the inventory between $t=1$ and $t=T$, i.e., the inventory from the first until the last quarter. The cost of produced product (CCP) is calculated as $CPP=CEF-CEI+CPV$. The model is shown in **Equation 1**.

$$\min_{cZ_{0t}^p, cZ_{0t}^{+p}, cX_{0t}^p} \frac{cZ_{0t}^{-p} + \sum_{t=1}^T cZ_{0t}^{+p} + \sum_{t=1}^T cX_{0t}^p}{cZ_{0t}^{-p} + \sum_{t=1}^T cZ_{0t}^{+p} + \sum_{t=1}^T cX_{0t}^p} \quad (1)$$

Subject to the constraints shown in **Table 2**.

Table 2 Constraints of the model DEA-OCT.

Projection constraints of outputs	$\sum_{k=1}^z CPV_{kt} \lambda_{kt} - S_{ykt}^+ = CPV_{0t}, t=1, 2, \dots, T$
Projection constraints of inputs	$\sum_{k=1}^z CPP_{kt} \lambda_{kt} + S_{xkt}^- = CX_{0t}^p, t=1, 2, \dots, T$
Constraints to links	$\sum_{k=1}^z CEF_{kt}^+ \lambda_{kt} + S_{zkt}^+ = CZ_{0t}^{+p}, t=1, 2, \dots, T$
	$\sum_{k=1}^z CEI_{kt}^- \lambda_{kt} + S_{zkt}^- = CZ_{0t}^{-p}, t=1, 2, \dots, T$
Intermediate equality constraints	$\sum_{k=1}^z CEF_{kt}^+ \lambda_{kt} - CEI_{k(t+1)}^- \lambda_{k(t+1)} + S_{zkt}^+ - S_{zk(t+1)}^- = 0, t=1, \dots, T-1$
Variational control constraints	$CX_{0t}^p - CZ_{0t}^{+p} + CZ_{0t}^{-p} = CPV_{0t}, t=1, 2, \dots, T$
Initial value constraints	$CZ_{01}^{-p} = CEI_{01}$
Scale constraints (variable return)	$\sum_{k=1}^z \lambda_k = 1$

Where:

cz_{0t}^{-P} : projection of the link cost of the input (initial stock cost) in period t.

cz_{0t}^{+P} : projection of the link cost of the output (cost of the final stock) in period t.

cx_{0t}^P : projection of the total optimal cost of the inputs in period t.

CEI_{0t} : initial cost of inventory, at the beginning of the period under analysis (equal to the cost of final inventory of the previous period t-1).

CEF_{0t} : final cost of inventory at the end of the period under analysis.

CPP_{0t} : cost of produced product of the period under analysis.

CPV: costs of products sold.

λ_{kt} : contribution of k-th DMU to the DMU under analysis.

S_{ykt}^+ : slacks of the outputs (or links of the outputs).

S_{xkt}^- : slacks of the inputs (or link of the inputs).

In summary, the model is relevant for calculating efficiency, preventing the possibility of obtaining a projection that ignores the relationship between variables, since this relationship always happens in practice in inventory control systems.

Because, in the analyzed set, there may be companies of different sizes, we opted for a variable scale model. The model was programmed and executed in MATLAB software.

We planned on running a single template configuration throughout the period (from 2010 to 2018). However, we had two limitations, Euronext stock data is not available in Economática and Carrefour Brasil (CRFB3) only opened its capital at B3 in 2016 and AMZN entered in the Brazilian market in the same year. Hence the need to investigate another model, a possibility envisaged by Cook et al. (2014). Another interesting question was to investigate the impact of a transnational company that operates exclusively by marketplace (MELI), in comparison to the others.

In this way, we executed six configurations of models: (1) all companies, except CRFB3 and AMZN, 2011-2018; (2) all companies except CRFB3 and AMZN, 2017-2108 (to investigate changes in the most recent period); (3) all companies except CRFB3, AMZN and MELI, 2017-2108 (to investigate the impact of MELI); (4) all companies except CRFB3 and MELI, 2017-2108 (to investigate AMZN's entry); (5) all companies except CRFB3, 2017-2108 (to investigate the entry of AMZN and MELI jointly); (6) all companies, **including CRFB3**, 2017-2108 (to investigate the efficiency of CRFB3 management, along with all available competitors, after its re-entry into e-commerce).

5. Results and Discussions

The first step was to investigate the net operating revenue to determine the size of the companies analyzed. **Table 3** shows the descriptive statistics of this variable.

Table 3 Net operating revenue (in dollars) of the analyzed companies.

DMU	Obs.	Average	Std. Dev.	Min.	Max.
<i>MGLU3</i>	31	2,050,828	961869.4634	636,004	3,750,972
<i>BTOW3</i>	31	1,468,623	747843.4113	444,257	2,998,206
<i>VVAR4</i>	31	5,217,594	2748997.112	1,321,757	11,204,135
<i>MELI</i>	31	377,601	292746.2856	61,460	1,398,095
<i>WMT</i>	31	290,585,781	134850702.2	104,189,000	500,343,000
<i>AMNZ</i>	31	57,571,419	39580908.04	9,857,000	177,866,000
<i>CRFB3</i>	7	8,971,051	4819995.031	3,748,895	15,199,516
<i>LAME4</i>	31	3,260,719	1611768.939	1,105,164	6,078,484

Table 3 shows that MELI has the lowest revenue, while WMT is the greatest. The average revenue for all companies added up is 27.2% of WMT revenue. Excluding the AMNZ, the sum of the revenues is equivalent to 7.3% to that of the WMT. Thus, there are two large companies, WMT and AMZ and the others are small when compared to revenues. In this way, the variable scale was justified in the model. **Table 4** shows the results of the six model configurations.

Table 4 Results of the tested configurations for the DEA-OCT model.

	1	2	3	4	5	6
	(2011 - 2018)	(2017 - 2018)				(2017 - 2018)
DMU	Efficiency	Efficiency				Efficiency
MGLU3	0.9511	0.9488	0.9949	0.9624	0.8944	0.8903
BTOW3	0.9606	0.9776	1	1	0.9763	0.9641
LAME4	0.9186	0.9462	0.9525	0.9467	0.9409	0.9175
VVAR4	0.9877	0.9424	0.9475	0.8766	0.8654	0.8316
WMT	1	1	1	1	1	1
MELI	1	1	-	-	1	1
AMNZ	-	-	-	1	1	1
CRFB3	-	-	-	-	-	0.9867

Model 1 (**Table 4**) presents WMT and MELI as efficient. WMT is a much larger company than the others and has physical stores (therefore has more stock), while MELI adopts the pure marketplace mode. The WMT is efficient in all investigated model, possibly due to a good strategy for a gain of scale. MELI is also efficient in all models where it is considered (1, 2, 5, and 6).

It is relevant that in the models where MELI is not considered (3 and 4), BTOW3 (another company that adopts pure marketplace mode) becomes an efficient DMU. This can mean a natural advantage of the marketplace mode to be efficient in inventory costs since this cost is

passed on to suppliers. Though, that, however, the exclusive adoption of the marketplace is not the unique cause for efficiency, since companies that do not adopt it have also been efficient (or almost).

Models 4 and 5 point out that whenever the AMNZ is considered, it is also among the efficient ones. Like MELI, AMNZ has a single distribution center in Brazil, i.e. they are companies with a small territorial coverage in a country of continental extension. Restricted coverage can also be one of the causes of their efficiency.

MGLU3 is the second most inefficient in Model 1, but its position goes up in Models 2 and 3, both referring to a more recent period and not considering AMZN, CRFB3 and, in the case of Model 3, not considering MELI neither. Improving efficiency for recent periods can demonstrate the application of new management practices. In that same period, MGLU3 is consistently more efficient than VVAR4, which went bankrupt. As the DEA part of the model measures the relative efficiency, it may be that the best (relative) performance of MGLU3 is due to the worse performance of VVAR4.

In Model 6, MGLU3 returns to the second most inefficient position and CRFB3 achieves a quasi-efficient condition. However, unlike AMZN, CRFB3 is not a new player as well as Máquina de Vendas is neither. The only difference there is an availability of recent data for CRFB3 and there is no for Máquina de Vendas. One of the limitations of the used tool is not being able to measure the size of our ignorance of the real population. Seeking a deeper investigation of the impact of CRFB3 in the available time frame, **Table 5** shows the efficiency results of Model 6 per quarter.

Table 5 Results of Model 6 by quarter.

DMU	(2017-2018)	1st 2017	2nd 2017	3rd 2017	4th 2017	1st 2018
<i>MGLU3</i>	0.8903	0.9316	0.9140	0.8999	0.8646	0.7053
<i>BTOW3</i>	0.9642	1	1	0.9702	0.9382	0.8673
<i>LAME4</i>	0.9176	0.9699	0.9807	0.8650	0.8962	0.7951
<i>VVAR4</i>	0.8316	0.8224	0.8331	0.8280	0.8553	0.5768
<i>WMT</i>	1	1	1	1	1	1
<i>MELI</i>	1	1	1	1	1	1
<i>AMNZ</i>	1	1	1	1	1	1
<i>CRFB3</i>	0.9868	0.9469	1	1	1	0.9338

As seen in Table 5, WMT, MELI, and AMNZ remain efficient in all quarters. CRFB3 presents 3 efficient quarters. This may demonstrate temporary difficulties in the process of implementation of good practices and in the resumption of e-commerce (first quarter of 2017), or that, for some reason, the company faces difficulties in being efficient in the first quarters (for example, the inventory can be impacted by the previous quarter - Christmas

sales).

It is interesting to remember that WMT, CRFB3, and AMZN have their marketplace strategy managed by the same company, Bling. Bling has been managing the AMZN's marketplace since the second quarter of 2017, the WMT's since the third and CRFB3's, since the third of 2018 (therefore, outside the analysis period). As WMT and AMZN are permanently efficient, it will be interesting to see if the CRFB3 will also achieve permanent efficiency too and how the management of Bling will contribute to this.

When comparing WMT with CRFB3, both are supermarkets and considered leaders of innovation in supply chain management, distribution network, and storage. It is important to remember that WMT is a larger company than CRFB3, though WMT has a smaller territorial scope, smaller distribution network, and fewer physical stores. This can mean a greater management challenge for CRFB3 and that CRFB3 may have better management practices so that it can be almost as efficient as WMT (in relative comparison). This possibility can be investigated with a case study.

BTOW3 was efficient in the first and second half of 2017 after that performance did not hold. Further investigation is needed to determine the cause. MGLU3 is more efficient only than VVAR3 in all periods. In the third quarter of 2017, MGLU3 is also slightly more efficient than LAME4. It is interesting to note that LAME4 and VVAR3 do not belong to the Novo Mercado, that is, they do not have a formal commitment to high standards of corporate governance. Suggesting that governance standards can also influence the efficiency of inventory cost management. Finally, we can understand that MGLU3 does not demonstrate a benchmark for optimized inventory cost management, although the valuation of its shares in B3 is extraordinary.

6. Final Remarks

We drew a narrative summary of the B2C e-commerce scenario for the Brazilian home appliance market, focusing on publicly traded companies. Additionally, we measured the cost inventory efficiency of the identified players. We identified four factors that may be impacting efficiency. Three factors positively affect it: (i) the adoption marketplace as an exclusive mode of selling; (ii) the culture of being innovative in supply chain management and distribution network; and (iii) the adoption of high standards of corporative governance. One factor negatively affect efficiency is the territorial coverage. Though, apparently the obstacles generated by huge distances can be overpassed by innovation and good management practices, as seen to be the case of Carrefour Brazil. Although its astonishing stock valuation,

Magazine Luiza is not a benchmark for inventory cost efficiency. Future studies should be focused on case studies of the players, mainly, MGLU3, CRFB3, WMT, and MELI.

We believe we successfully contributed with the literature of a topic that, although its relevance, is still scarce and far from consolidated - B2C e-commerce in emerging markets.

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