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Efficiency determinants in retail stores: a Bayesian framework

A. George Assaf [a,*], Carlos Barros [b], Ricardo Sellers-Rubio [c]

[a] Isenberg School of Management, 90 Campus Center Way, 209A Flint Lab, University of Massachusetts, Amherst 01003, USA
[b] Instituto de Economia e Gestão, Technical University of Lisbon Portugal
[c] Department of Marketing, University of Alicante Spain

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ABSTRACT

This paper analyzes the impact of vertical integration, age, geographic expansion, and low price strategy on the cost efficiency of retail stores. We test our hypotheses using the innovative Bayesian frontier methodology. The data involve a sample of Spanish retail stores that operate in a highly competitive and dynamic environment. From the results, it is clear that cost efficiency is higher for stores that have: longer years in business, stronger geographical presence, and lower price offerings. Vertical integration, on the other hand, is negatively related to efficiency. Further discussions of these findings and related managerial implications are provided in the paper.

1. Introduction

The level of competition in the retail industry has intensified in recent years, driven by several factors such as the decline in household wealth, rising unemployment, tight credit conditions, rapid globalization, unclear economic picture, drop in consumers' confidence index, and increase in merger and acquisition activity. In fact, it is very common today to find several retail stores competing for a slice of market pie that rarely varies in size and often saturated. Consumers have also become extremely price conscious, especially as retailers constantly fight for each dollar by offering substitutable products at lower prices [1,2]. Weekly specials including catalogues and additional marketing are also used intensely to attract consumers and drive sales. While the winner of this price war is the consumer, retailers have to survive with lower profit margin which necessitates a stricter control of productivity and a decrease of operational wastages, especially as the industry is traditionally known to be labour intensive.

In the retail literature, the need for higher productivity has also been highlighted as one of the key issues for future survival. Numerous studies have recently appeared, addressing the performance challenges of several retail markets, such as Portugal, the US, and France [1–4]. The key message from most of these studies is that efficiency measurement is of vital concern at both the store level and the strategic level, since it helps retailers differentiate themselves from other competitors. Studies dealing with some store-specific characteristics that affect retail performance have also appeared in the literature.

Within the growing importance of performance measurements in retail, more advanced methodologies have also been introduced. In contrast to the traditional literature where simple ratios were the most adopted productivity methods, significant volume of work currently exists in the area of measuring production efficiency by estimating an "efficient frontier" that serves as a benchmark for evaluating performance. The most adopted methods for that purpose include the stochastic frontier (SF) and data envelopment analysis (DEA) methods [5–9]. The advantage of both these methods is that they allow the use of multiple inputs and outputs in the measurement of performance, making them thus more suitable in the retail context. Although the DEA method is a nonparametric, deterministic approach that defines a relationship between multiple spending inputs and outputs by building an efficient frontier, it has been critiqued for not providing fit statistics such as r-square or p-value that can be used for statistical inferences [10]. The SF method, on the other hand, uses a parametric approach by explicitly taking into account the stochastic properties of the data [1,19].

The aim of this study is driven by all of the above, and the motivation is to extend the existing literature by offering more accurate insights into the performance determinants of retail stores. Specifically, the study focuses on analyzing on the supermarket industry, which is traditionally known to be very competitive. Most supermarkets operate on a high inventory turnover usually with low profit margins, which suggests that retail mark up for each individual product is very low. In most

* Corresponding author. Tel.: +1 413 5451492.
E-mail addresses: assaf@ht.umass.edu (A.G. Assaf), cbarros@iseg.utl.pt (C. Barros), Ricardo.Sellers@ua.es (R. Sellers-Rubio).

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countries, supermarkets compete against national, regional, local and independent supermarkets, specialty food stores, club stores, drug stores, convenience stores, discount merchandisers, and other local retailers. They compete on the basis of price, store location, product mix or types of products and brands and services. The industry's small mark up price format indicates that price is extremely significant. In other words, supermarkets rely on low mark up and high sales volumes as opposed to higher mark up and lower volume of sales. Is this context, efficiency analysis constitute a useful and interesting tool to improve the profitability of supermarket chains.

Most existing studies in the literature have generally focused on the estimation of efficiency without providing an in-depth analysis to the factors that lead to efficiency variations between retail stores. The sole focus on efficiency makes the study also limited to one sample or one geographic area of analysis. However, as this study focuses on identifying the sources of efficiency, the results can be more applicable to other retail sectors, or even to the same retail sector in other countries. The methodology used in this study also provides an innovation to the existing literature. For the first time, we use the Bayesian methodology that has several advantages over the maximum likelihood (ML) traditionally used to estimate the SF approach. For instance a key advantage of the Bayesian approach is that it allows the inclusion of "prior" information about parameters in inferences. With Bayesian, the results are also usually presented in terms of probability density function (pdfs), making it thus possible to make probability statements about the model parameters.

In testing our hypotheses we use a sample of Spanish retail supermarkets. There are several interesting characteristics of the Spanish retail market that allow us to test our desired hypotheses. In the next section we provide a brief overview of the Spanish retail market. This is followed by the literature review, methodology, data characteristics/hypotheses, discussions, and concluding remarks.

2. Contextual setting

In recent years, the Spanish supermarket industry has been characterized by a series of changes that have affected its structure and performance [11]. Among them, four critical factors deserve special attention.

First, the significant growth of self-service establishments in comparison to traditional stores [12]. Specifically, supermarket chains have become one of the main players in grocery retailing in almost every Spanish city [13] and, in recent years, have earned significant market shares from traditional stores and hypermarkets. In 2007, for instance, supermarkets covered more than of the 73% market share for food products, with the leading supermarket chain –*Mercadona* – having more than 1000 supermarkets. Furthermore, traditional hypermarket operators have developed the supermarket format—for example, *Auchan* (*Alcampo* in Spain) with *Sabeco* Supermarkets; *Carrefour* with *Carrefour Express*; similarly with distribution groups—for example *El Corte Inglés* with *Supercor*.

Second, the Spanish supermarket industry has been characterized in recent years by an increase in market concentration [14,15]. This increase has been the consequence of the growing size of companies, which has been used to gain stronger market power on both sides of the distribution channel. First, in terms of consumers, there could be a negative impact on prices [14] and, second, the relationship between manufacturers and retailers has become more asymmetric. As an example, the market share of the five leading companies (by selling area) has grown from 42.95% in 2001 to 59% in 2007, whereas the participation of the first 10 companies has grown from 62.64% to 74% in 2007. To be precise, companies with the greatest market share in 2007 are the French company *Carrefour*, and the Spanish companies *Mercadona* and *Grupo Eroski*.

Third, it is important to stress the significant increase in inter-type competition among different commercial formats [16]. Although the differences between the services provided by various intermediaries justify the coexistence of several commercial formats (e.g. convenience stores or supermarket chains) [17], the relevant markets of the different commercial formulas in Spain are overlapped as consumers use different formats depending on the type of purchase. This implies strong complementariness and substitutability relationships among commercial formats. It also leads both establishment types to provide the same type of products and to be considered by consumers as competitive alternatives.

Finally, it is also important to highlight the progressive incorporation of new commercial techniques, especially new information and communication technologies (ICTs). These technologies have mainly been introduced by foreign firms operating in Spain (e.g. Carrefour) and supported by the continual proliferation of retail associations. The implantation of technological and management innovations (e.g. scanner systems, EDI, ECR, Rack Jobbing, DPP) as sources of competitive advantage towards better customer satisfaction should be particularly stressed. ICTs have changed the production and management structures of supermarkets, allowing more and more complicated real time operations, more efficient stock management as well as the development of new products and services, favouring productivity improvements [18].

3. Literature review

There are two competing scientific methods to analyze efficiency: the stochastic frontier (SF) and the DEA. Several papers exist in the retailing literature using either of these methods or a combination of two. In Table 1, we summarize these papers presenting the models and the inputs and outputs used.

We can observe that most authors have used the DEA method and that there are only few papers using the econometric models. Sellers and Mas [19] estimated a production function of Spanish retailers and compared it with the DEA models. Another European application includes Barros [1] who used a DEA model to analyze the efficiency of Portuguese retail outlets. Productivity at an aggregate level has been analyzed in the USA by Ratchford [2]. The author used a cost function with the associated share equation and concluded that the industry registered a modest degree of growth in total productivity between 1959 and 1995. Betancourt and Malanoski [20] explored the growth in specific types of services offered by a sample of US supermarkets with an econometric simultaneous model. They concluded that there are evidences of constant returns to scale in either output or turnover, but increasing returns to scale with respect to the provision of distribution services. Ofer [21] also found substantial economies of scale in the Israeli retail sector and Oi [22] underlined a positive association between store size and transaction size. The provision of broader and deeper assortments is the reason for larger store size and also the source of scale economies [23].

This brief literature review shows that there are no published papers analyzing the efficiency of supermarket companies with the use of the Bayesian approach. Most studies have adopted the DEA method that suffers from statistical limitations. More importantly, most available studies have focused the analysis on the efficiency of retails stores without providing an in-depth

analysis to the factors that lead to the efficiency variations between retail stores.

4. Stochastic frontier: the Bayesian framework

The stochastic frontier model used in this study can be simply expressed as

$$C_{it} = g(\mathbf{x_{it}},\boldsymbol{\beta}) + v_{it} + z_{it}, \quad (i = 1,...,N; t = 1,...,T) \tag{1}$$

where C_{it} is the natural logarithm of total cost for retail store i at time t, $\mathbf{x_{it}}$ a vector of exogenous variables,g a known functional form, $\boldsymbol{\beta}$ a vector of unknown parameters which define the deterministic part of the frontier technology, and $v_{it}$and z_{it} are two random terms, one is symmetric around zero and represents measurement noise, and the other is non-negative and capture the impact of cost inefficiency. We follow here Koop et al. [24] and make the assumption that $z_{it} = z_i (t = 1,...,T)$. The individual cost efficiency measures are usually expressed as $r_i = \exp(-z_i)$, which is quantity in (0,1].

The Bayesian estimation of the model in Eq. (1) requires specifying the likelihood function and the prior distribution of the model parameters[1] . For specifying the likelihood function we follow here most studies in the literature we assume that $v_{it}$is $N(0,\sigma^2)$, i.e. normal with zero mean and constant variance and z_{it} follows an exponential distribution with mean (and standard deviation) λ_i. The mean of z_{it} can also vary with some $(m-1)$ exogenous variables $s_{ij} (j = 2,...,m)$ explaining possible variations between cost efficiency. We assume that

$$\lambda_i = \prod_{j=1}^{m} \phi_j^{-w_{ij}} \tag{2}$$

where $\phi_j > 0$ are unknown parameters, $s_{i1} = 1$ and $m > 1$ (the distribution of $z_i$can differ for different i). Note that in a special case when $m = 1$ (then $\lambda_i = \phi_1^{-1}$), this amount to assuming that the exogenous variables do not have a strong impact in explaining the sources of cost inefficiencies. The full Bayesian model for (1) can be expressed as

$$\begin{aligned} p(\mathbf{C},\mathbf{z},\boldsymbol{\theta}|\mathbf{X},\mathbf{S}) &= p(\boldsymbol{\theta})p(\mathbf{z}|\boldsymbol{\theta},\mathbf{X},\mathbf{S})p(\mathbf{C}|\mathbf{z},\boldsymbol{\theta},\mathbf{X},\mathbf{S}) \\ &\propto p(\boldsymbol{\theta}) \prod_{i=1}^{N} \left[f_G\left(z_i \middle| 1, \prod_{j=1}^{m} \phi_j^{s_{ij}} \right) \prod_{t=1}^{T} f_N^1 (C_{it} | g(\mathbf{x}_{it},\boldsymbol{\beta}) + z_i, \sigma^2) \right] \end{aligned} \tag{3}$$

where $\mathbf{s}_i = (s_{i1},...,s_{im})$, $\boldsymbol{\theta} = (\boldsymbol{\beta}',\sigma^2,\phi_1,...,\phi_m)'$ is a vector of the parameters of the model, $p(\boldsymbol{\theta})$ denotes the prior density, $f_N(.|a,b)$ the univariate normal density with mean a and variables b, and $f_G(.|a,b)$ the Gamma density with mean a/b and variance a/b^2($a = 1$ corresponds to the exponential distribution).

The prior distribution $p(\boldsymbol{\theta})$ can take any form, but it is common in the stochastic frontier estimation to use a non-informative prior to avoid providing subjective information about the parameters. Thus, we use here the following prior:

$$p(\theta) = p(\sigma^2)p(\boldsymbol{\beta})p(\phi) \propto f_G\left(\sigma^{-2} \middle| \frac{1}{2}n_0, \frac{1}{2}c_0\right) I(\boldsymbol{\beta} \in B) \prod_{j=1}^{m} f_G\left(\phi_j \middle| 1, g_j\right) \tag{4}$$

which indicates no prior information about the parameters, except for regularity conditions $\boldsymbol{\beta} \in B$ imposed by economic theory and represented by the indicator function $I(.)$. Note that n_0 and c_0 are non-negative hyperparameters. Following Koop et al. [24] and Marzec and Osiewalski [25] we also use $g_j = 1$ for $j > 1$ and take $g_1 = -\ln(r^*)$, where r^* is the prior median of the efficiency distribution, and it is exactly the median of the marginal prior distribution for individual efficiency $r_i = \exp(-z_i)$; see Koop et al. [24] for more details.

The posterior corresponding to these priors is intractable and must be analyzed using simulation methods. In particular, a Gibbs sampler with data augmentation can be set-up for this model (see [24,26]) involving the following posterior density for the frontier parameters and precision σ^{-2}For $\boldsymbol{\beta}$

$$p(\boldsymbol{\beta} \middle| \mathbf{C},\mathbf{X},\mathbf{S},\mathbf{z},\sigma^{-2},\phi) \propto I(\boldsymbol{\beta} \in B) f_N^k(\boldsymbol{\beta}|\hat{\boldsymbol{\beta}},\sigma^2(\mathbf{X}'\mathbf{X})^{-1}) \tag{5}$$

where $\hat{\boldsymbol{\beta}} = (\mathbf{X}'\mathbf{X})^{-1}\mathbf{X}'(\mathbf{C} - \mathbf{z} \otimes \boldsymbol{\eta}_T)$, $\boldsymbol{\eta}_T$a vector of ones and $\otimes$ the Kronecker product between $\mathbf{z}$and $\boldsymbol{\eta}_T$.For ϕ_j

$$p(\phi_j|\mathbf{S},\mathbf{z},\phi_{(-j)}) = f_G\left(\phi_j \middle| 1 + \sum_i s_{ih}, g_h + \sum_{i=1}^{N} s_{ih} z_i \prod_{j \neq r}^{m} \phi_j^{s_{ij}} \right) \tag{6}$$

For $\mathbf{z}$

$$p(\mathbf{z}|\mathbf{C},\mathbf{X},\mathbf{S},\boldsymbol{\theta}) \propto \prod_{i=1}^{N} f_N^1 \left(z_i \middle| \bar{C}_i - \bar{\mathbf{x}}_i\boldsymbol{\beta} - T^{-1}\sigma^2 \prod_{j=}^{m} \phi_j^{s_{ij}}, T^{-1}\sigma^2 \right) I(z_i \geq 0) \tag{7}$$

and

For σ^{-2}

$$\begin{aligned} p(\sigma^{-2}|\mathbf{C},\mathbf{X},\mathbf{S},\mathbf{z},\boldsymbol{\beta},\phi) &= p(\sigma^{-2}|\mathbf{C},\mathbf{X},\mathbf{z},\boldsymbol{\beta}) \\ &= f_G\left(\sigma^{-2} \middle| \frac{n_0 + T \cdot N}{2} \cdot \frac{1}{2} \left\{ c_0 + \sum_{i,t} (C_{it} - z_i - h(\mathbf{x}_{it},\boldsymbol{\beta})^2 \right\} \right) \end{aligned} \tag{8}$$

The data, model specification, and results are provided in the following sections.

5. Data

The sample is taken from Spanish self-service retail establishments in the general grocery retail sector, with retail selling areas of between 400 and 2500 square meters (supermarkets). The estimation of efficiency requires homogeneous units, so in order to guarantee the consistency of the companies analyzed, hypermarkets were excluded, because the assortment and services provided to consumers are quite different from supermarkets.

During the period considered there were a series of mergers and takeovers, the extinction of some supermarket chains and the appearance of new companies that did not exist in the base year. The adopted solution is to use a complete panel, eliminating companies which, as a consequence of being taken over or merging, have disappeared from the sample. Despite the loss of information that this could provoke, this option is advisable in our case as the majority of mergers/takeovers affecting the initial sample occurred in the final years of the temporal period considered, which means that the belated integration of the companies involved would create a lot of fictitious companies when estimating the efficiency frontier. The final sample is comprised of 77 supermarket chains operating continually from 2001 to 2007. Despite the apparently reduced number, these companies represent more than 75% of total supermarket sales for the period considered in Spain.

The sources used to obtain the variables employed are the ALIMARKET database (one of the most important retailing databases in the Spanish market, which collects financial and marketing data from the most important supermarkets), the

[1] The Bayesian theorem can be expressed as $p(\theta|y) = L(y|\beta,\sigma) \times P(\theta)$ where $p(\theta|y)$ is the posterior probability density function, $L(y|\beta, \sigma)$ is the likelihood function that summarizes the information contained in the data, $p(\theta)$ is the probabilistic statement or belief about the parameters before (prior to) obtaining the data. The posterior underpins all types of Bayesian inference, including point and interval estimation, evaluation of hypotheses and prediction.

Distribution Yearbook, and the SABI database, which provide accounting information on Spanish companies. As we use panel data, monetary values are deflated by the consumer price index (CPI) provided by the National Statistical Institute and is expressed in constant 2001 euros.

A considerable amount of theorizing and empirical research has been done on the correlates of retail labour productivity [27]. These correlates can be classified as: (i) marketing variables (store location, price levels, inventory investment, and advertising expenditures); (ii) characteristics of a retail firm (type of store and legal form of ownership); and (iii) traditional economic correlates (wages, capital to labour ratio and scale or size of firm) (e.g. [27–31]; [32,2]). However, empirical papers analyzing the correlates of retailing efficiency are scarce, and most existing studies are based on retail banking (e.g. [33]). Sellers and Mas, [11] analyze the effect of inventory investment per square meter, wage level per employee, and age of the firm on retailers efficiency, while De Jorge [34] assess the effect of regulatory conditions (more or less restrictions to new openings) on retailers efficiency. Thus, this paper is one of the first steps towards identifying those factors that impact retail efficiency. Specifically, we aim to test the relationship between retail efficiency and the following covariates: vertical integration strategy, age of the firm, national vs. local strategy, and price strategy. More justification about the selection of each of these covariates is provided in the following sub-sections.

5.1. Vertical integration and efficiency

Vertical integration has been a topic of interest to economists over several decades [35]. Vertical integration provides common ownership over successive levels of the supply chain and facilitates internal exchange instead of market or contractual exchange [36]. Vertical integration of the production stages in retailing emerges whenever there are economic efficiency advantages over specialized non-vertically linked production, reducing transaction costs by mitigating contractual inefficiencies between non-integrated suppliers and customers. In a simple situation where there are a manufacturer, a wholesaler and a retailer, the wholesaler has a marginal cost (the price set by the manufacturer), and to make profits has to sell above its marginal cost. The retailer has a marginal cost as well, which is usually the price that the wholesaler sets. The retailer will then set a price to the consumer above this price. When there is vertical integration, the new retailer (the result of the integration between the wholesaler and the retailer) now provides the product directly to the consumer and the only mark up is to the consumer. The profit maximizing price to the consumer is lower than before, increasing the efficiency of the whole system.

From the point of view of the supply chain management, some authors analyze the effect of vertical integration on the efficiency of the firms involved. For example, Golany et al. [37] developed an efficiency measurement framework for systems composed of two subsystems arranged in series that simultaneously computes the efficiency of the aggregate system (vertical integration) and each subsystem. Their findings suggest that managers of each subsystem will not agree to "vertical integration" initiatives unless each subsystem will be more efficient than what each can achieve by separately applying conventional efficiency analysis.

In this sense, Axelsson et al., [38] argue that insourcing decisions – i.e. assuming processes presently performed by outside suppliers – are results of a continuous process where the firm evaluates factors that affect vertical integration to make the most efficient operations. McLaren [39] points that the efficiency gains associated with vertical integration take the form of lower fixed costs for downstream firms. Following this argument, Avenel [40] shows how the profitability of vertical integration is related to the ability of integrated firms to coordinate on the adoption of specific technologies associated with a lower marginal cost.

Consequently, the following hypothesis is proposed:

H_1: Vertical integrated retailers are more cost efficient than non vertical integrated retailers.

5.2. Price strategy and efficiency

In the field of industrial organization two alternative theories have been put forward to explain the relationship between market structure (market concentration and market share) and performance. On the one hand, the traditional hypothesis of market power [41] proposes that high market concentration and/or market share is associated with less favorable prices for consumers, which will in turn generate higher profits for producers. Companies operating in concentrated markets can adopt collusive behavior, charging higher prices for their products. In fact, in a concentrated market, firms have incentives to cooperate as opposed to competing because if they are able to coordinate their actions and there are no potential entrants into the market, they can behave monopolistically and maximize the joint profits of the industry.

On the other hand, the efficient structure hypothesis [42,43] proposes that concentration and/or market share are positively correlated with a firm's efficiency, so that the most efficient companies grow more and obtain dominant market shares. Under this hypothesis, high concentration and market share are associated with more favorable prices for consumers if some of the savings made through the efficiency are passed on to the consumers (possibly as a part of the process of reaching dominant market shares). A greater efficiency of companies operating in more concentrated markets and possessing higher market shares would also produce higher profits. In summary, this hypothesis holds that efficiency explains profitability and concentration (and/or market share). In other words, the positive association between profitability and concentration is due to the greater efficiency of large companies and not to the exercise of monopolistic power in the industry.

One of the characteristics of the Spanish supermarket industry is the presence of a small group of large companies with high market shares, along with an atomized market structure with a large number of agents, which creates a situation between the conditions established in the models of perfect competition and monopoly. Sellers and Mas [44] showed that the competitive situation characterizing the supermarket sub-sector in Spain is that of a modified efficient structure. Under this hypothesis it is supported that more efficient firms can charge lower prices than competitors, enabling them to capture larger market shares and economic rents.

Maintaining this strategy requires a continuous search for cost reductions emphasizing efficiency gains. In fact, under the cost leadership competitive strategy proposed by Porter [45,46], a firm's relative position within its industry determines whether its profitability is above or below the industry average. Under this strategy, a firm sets out to become the low cost producer in its industry. The sources of cost advantage are varied and depend on the structure of the industry. They may include the pursuit of economies of scale, proprietary technology, preferential access to raw materials, and other factors. A low cost producer must find and exploit as many sources of cost advantage as possible (reducing unit manufacturing costs through higher unit volume, efficient scale facilities, and experience curve, exercising strict

cost control over engineered costs, and minimizing discretionary costs such as R&D, service, sales force, advertising or quality control). If a firm can achieve and sustain overall cost leadership, then it will be an above average performer in its industry, provided it can command prices at or near the industry average. At the end, cost efficiency enables the retailer to sell its products to many customers at the lowest competitive price and such low prices will provide competitive advantage and lead to an increase in market share [47,48].

Consequently, we propose the following hypothesis:

H_2: Low price retailers are more cost efficient than non-low price retailers.

5.3. Age of the firm

The effect of experience on a firm's productivity is a question seldom addressed in the literature. In principle, a positive relationship between the seniority of a company and its sales and profits might be expected. Thomas et al. [49] has described the age of firm as one of the key components of a firm's experience and learning curve. In fact, as a store becomes established within the business community, awareness and reputation are expected to become more widespread along with positive word-of-mouth [49].

In the particular case of efficiency, and generally speaking, greater seniority affords the company greater know-how, which can lead to a greater capacity for developing its activities in a more efficient way [49]. In the case of firm experience – typically measured by firm age – Berger and Mester [33] consider that a firm's age might be related to cost efficiency since firm production might involve "learning by doing". Consequently, the following hypothesis is put forward:

H_3: The age of a supermarket chain has a positive effect on its cost efficiency.

5.4. Geographic expansion

After the Spanish Retail Trade Act in 1996 some supermarket chains, and not only the largest, proceeded to increase the number of outlets outside what until then had been their traditional geographic scope of operation. Two competing theories arise to explain this relationship between geographic expansion and efficiency, although the results are not clear.

On the one hand, previous studies support the hypothesis that positive link exists between efficiency and distance (derived from geographic expansion). Geographic expansion may allow efficiently managed institutions to "export" their superior managerial skills, policies and procedures to their affiliates, take advantage of network economies, allowing scale or scope economies that reduce costs [50]. In this line, Petersen and Rajan [51] found a positive relationship between distance and labour productivity, mainly due to the increasing role of technology. When an industry is relatively information intensive, it could take meaningful advantage of the benefits of information processing and telecommunications, enabling firms to screen and monitor their business at greater distances [52].

On the other hand, if "agency costs of distance" exist, then additional expenses or lost revenues arise as managers have more difficulty monitoring and controlling local business from a greater distance [53]. If expansion takes place over geographically distant markets (i.e. other provinces) it could lead to a decrease in the performance of firms seeking presence in other markets (which are further away than the natural market), because of the existence of agency costs related to distance and lack of control. Should these effects exist, there would be evidence in favour of a negative link between distance and productivity growth. However, technology can offset these negative effects, mitigating the negative effect of distance (expansion in other markets) on productivity growth [52]. Actually, Sellers and Mas [18] suggest that technological progress in the Spanish retail industry may have led to productivity improvements, and these findings would be consistent with the hypothesis of improved control over distant outlets and reduced agency costs of distance.

Further, expansion in the natural market (a "defensive strategy" consisting in growing only in one province) which by definition is physically closer to headquarters than "other markets" could also be beneficial in terms of efficiency gains for the firm as firms in their natural market enjoy lower transportation and monitoring costs. However, the positive link between expansion in natural markets and efficiency gains could effectively emerge if firms were able to reduce some inherent costs associated with the industry as well as establishing long-term relationships with clients.

Thus, derived from these arguments we propose the following hypothesis:

H_4: Firms operating in various provinces are more cost efficient than retailers operating only in their natural market.

6. Results

We estimate the Bayesian frontier model[2] in this study using data on 74 retail stores over $T=7$ years. The functional form of the model is a restricted translog and can be expressed as follows[3]:

$$\begin{aligned}\ln(C_{it}/PK_{2it}) &= \beta_0+\beta_1\ln(PL_{it}/PK_{2it})+\beta_2\ln(PK_{1it}/PK_{2it})+\beta_3\ln(AV_{it})\\ &+\beta_4\ln(PL_{it}/PK_{2it})\ln(PL_{it}/PK_{2it})+\beta_5\ln(PK_{1it}/PK_{2it})\ln(PK_{1it}/PK_{2it})\\ &+\beta_6\ln(PL_{it}/PK_{2it})\ln(PK_{1it}/PK_{2it})+\beta_7\ln(AV_{it})\ln(AV_{it})\\ &+\beta_8\ln(AV_{it})\ln(PL_{it}/PK_{2it})+\beta_9\ln(AV_{it})\ln(PK_{1it}/PK_{2it})\\ &+\beta_{10}t+v_{it}+z_{it}\end{aligned} \quad (9)$$

where $C_{it}$is the total cost, PL_{it} the price of labour calculated as a ratio of labour expenses to number of employees, PK_{1it} the price of capital premised calculated by dividing the total depreciation by total assets, PK_{2it} the price of return on capital calculated by dividing profits between capital (equity plus debt), AV_{it} the total added value and represents the output in our model, and t the time trend to capture any missing dynamic. Note that as described before, we allow the inefficiency termz_{it} to vary with four exogenous variables[4] and these include s_{i2} is a dummy variable that takes the value of 1 for retail store that follow a vertical integration strategy (retailers that handle directly with the manufacturers) and zero otherwise (retailers that use wholesalers to handle with manufacturers), s_{i3} a dummy variable that takes the value of one for old and well established stores, and zero otherwise, s_{i4} a dummy variable that takes the value of one for stores that have presence in multiple provinces and zero otherwise (outlets in one province), and s_{i5} a dummy variable

[2] The Winbugs software was used to obtain the Bayesian results.

[3] Note that other popular forms such as the Cobb–Douglas and full translog were also tested using the deviance information criterion (DIC) but did not prove to be a better fit than the above model. Models will the lowest DIC are usually the best fitting models.

[4] The approach explained in Section 4, and which is associated with Koop et al. [24] allows only for dummy determinants of inefficiency. This is not a general approach to efficiency analysis, since it also rests on the restrictive assumption of an exponential distribution for inefficiencies. It does allow for convenient posterior conditional distributions but in other respects it is not to be adopted seriously. Regarding recent advances in efficiency analysis please see the following references: [54–57].

that take the value of one for low price stores (discounters and every day low price–EDLP- strategy) and zero otherwise.

The posterior results for the above model were obtained using 50,000 iterations, after discarding 10,000 initial draws. The posterior means and standard deviations of the parameters are expressed in Table 2. We first confirmed that the parameters of the input prices and output are of the correct sign with total cost increasing with each of these variables [58]. In Figs. 1 and 2 we also present the correlation matrices and the Brook, Gelman, Rubin (BGR) statistic for some of the model parameters[5]. A high correlation usually leads to inconsistent parameter estimates. It is clear from Fig. 1, that there is no correlation pattern between the reported model parameters. We also confirmed that this is the case between the other parameters in the model. In terms of the BGR, this statistic assesses the variability within parallel chains as compared to variability between parallel chains. The model is judged to have converged if the ratio of between to within variability is close to 1. The green line in each plot represents the between variability, the blue line represents the within variability, and the red line represents the ratio. Evidence for convergence comes from the red line being close to 1 on the y-axis and from the blue and green lines being stable (horizontal) across the width of the plot. As it is clear from Fig. 1, all reported parameters have BGR close to 1, confirming therefore the convergence of the model.

In Table 3 we provide the results for the parameters $\gamma_j = \ln(\phi_j)$ which reflect the impact of our dummy variables on the efficiency of retail stores[6]. The results suggest that all variables expect the one associated with "vertical integration" have a positive impact on the efficiency of retails stores. The results thus do not support hypothesis 1. One possible interpretation is that the integration advantages are compensated for the possible negative effects an integrated firm will have from maximizing an integrated objective function. In fact, Mansson [59] findings connect vertical integration and efficiency points in two directions: both in favour for non-integrated firms and in favour for fully integrated firms. Since the seminal work of Coase [60], the literature has developed several theories that explain what determines the vertical boundaries of a firm. The efficiency rationale, as studied under the transaction cost economics and property rights theories, suggests that vertical integration reduces transaction costs by mitigating contractual inefficiencies between non-integrated suppliers and customers and provides incentives to make relationship-specific investments. However, in addition to this efficiency argument, the foreclosure argument suggests that a vertical integration with a supplier (customer) enhances the market power of the integrated, and this could lead to lower efficiency rates. Another possible explanation is given from Grossman and Hart [61], who focus on the efficiency related to different levels of vertical integration. The study implicates that different levels of integration result in different objective functions, and thereby it is also possible to derive different results concerning efficiency.

The results obtained also imply that firms with a lower price strategy are more efficient than firms that do not follow this strategy, supporting hypothesis 2. This result was expected as retailers selling their products at the lowest competitive price need higher cost efficiency to make up for the loss of revenues. Lowering the price also allow retailer to gain competitive advantage and increase market share [47,48]. Subsequently, this allows them to maintain the low cost base and gain cost efficiency, which is the primary determinant of the cost leadership strategy. The results also support hypothesis 3. This indicates a positive effect of experienced supermarkets on efficiency, as it involves "learning by doing" in firm production and greater know-how, which may lead to greater capacity for carrying out activities in a more efficient way [49].

Finally, the results also allow us to support hypothesis 4, as supermarket chains with outlets in different provinces (geographic expansion) are more cost efficient than supermarket chains with stores only in their natural market (one province). This finding could be of particular importance in the Spanish retail sector, which has recently witnessed rapid geographic expansion. Many Spanish regions however still enforce limitations on the number of licences that can be offered to commercial establishments. This creates in many cases space monopolies, and increases the market power of the already established supermarkets. The results obtained in this paper support the idea that supermarket chains that followed an expansion strategy are more cost efficient. This could be related to the fact that when a supermarket expands its activity to another province, it has more incentives to increase cost efficiency in order to compete in this new market, or gain additional market share. Similar findings were also reported by De Jorge [34] who showed that retailers operative in areas with low restrictions to a new opening (what implies more competition between incumbent and new supermarkets) are more efficient than those located in areas of greater regulation.

Further confirmations on the impact of the above variables on cost efficiency are illustrated in Table 4 where we provide the mean efficiency scores according to the various groups involved. As it is clear, supermarkets with low price, multiple stores, and older age are the most efficient. Supermarkets with no vertical integration, on the other hand, have a higher average efficiency score (65.84%) than vertically integrated supermarkets (60.83%). The individual efficiency results of each retail store in the sample can also be obtained from the authors upon request.

7. Discussion and conclusions

Growing competitiveness among retail companies and the globalization of markets have given rise to an economic environment in which it is becoming increasingly difficult for companies to survive. In today's extremely competitive environment, consumers are more demanding than ever as they constantly seek immediate access to products at lower prices. In this context, the analysis of efficiency has become an important issue in the retail sector [62]. Efficiency favors intermediary management, playing an important role in the control and management of retail firms. Efficiency analysis also provides vital information for a number of tactical, strategic, and policy related decisions in the retail industry [63]. At a tactical level, for a multi-unit firm, a manager's control and expansion strategies begin with an assessment of the relative store efficiency level. Strategically, retail efficiency can be used to differentiate firms and provides the foundation to develop strategies for growth and diversification.

This paper extended the existing literature by offering more accurate insights into the performance determinants of retail stores. The model used in this study also presents a new contribution to the retail literature. The results obtained imply that stores with lower price strategy, longer existence in the market, and multiple geographical presences are more efficient

[5] For space limitation, we only report here the correlations matrix and BGR plots for some parameters of the model. Details about the other parameters can be obtained from the authors upon request.

[6] While the results are not reported here, we also conducted here a DEA double bootstrap approach to estimate the impact of the dummy variables on the efficiency results. It was clear that the results are in line with our Bayesian approach reported in Table 3. For detail about the DEA double bootstrap approach refer to Simar and Wilson [81].

Table 1
Research into retail efficiency.

Papers	Method	Units	Inputs	Outputs
Athanassopoulos [76]	DEA	Restaurants	Adjustable inputs: (1) the bar area (ft^2) and (2) the number of covers. Uncontrollable inputs: (1) market size (potential customers), (2) the number of restaurants in a 1-mile radius, and (3) the number of restaurants in a 3-mile radius	(1) Food sales (in value) and (2) sales of beverages (in value)
Athanassopoulos [76]	DEA	UK grocery retailers	(1) Number of outlets, (2) fixed assets, (3) capital employed, and (4) number of employees	(1) Sales
Thomas et al. [49]	DEA	500 domestic retail outlets of a leading specialist retailer in the USA	16 inputs: (1) average number of full-time employees per square foot of selling space times 10,000; (2) the ratio of the average number of full-time to part-time employees; (3) the total annual salaries and wages divided by payroll hours; (4) the average hourly employee tenure in years; (5) the average length of store managers' tenure in years; (6) the age of the store in years; (7) the base rent plus other occupancy expenses, divided by the total square footage of the selling space; (8) dollars of annual operating expenses per store; (9) population per store in the market; (10) the average annual household income in a 2-mile radius; (11) the number of households in a 2-mile radius; (12) the distance in miles to the nearest alternative store; (13) the total average inventory at cost, in dollars; (14) the average dollar size of transactions; (15) the percentage of annual turnover; and, lastly, (16) the dollar shrinkage divided by inventory dollars.	(1) Sales and (2) profits
Donthu and Yoo [10]	DEA	24 outlets of a fast-food restaurant chain	(1) Store size, (2) manager tenure, (3) store location (inside a shopping mall versus free-standing), and (4) promotion/give-away expenses.	(1) Sales (value) and (2) customer satisfaction (a 5-point scale).
Barros and Alves [77]	DEA-CCR and BCC model	47 outlets of a Portuguese hypermarket retail company: 1999–2000	(1) Full-time employees, (2) part-time employees, (3) cost of labour, (4) absenteeism, (5) area of outlets, (6) number of points of sale, (7) age of outlet, (8) inventory, and (9) other costs	(1) Sales and (2) operating results
Keh and Chu (2003)	DEA BCC model	13 US stores 1988–1997	Labour [(1) floor staff and (2) management wages and benefits for the number of hours worked)] and capital [(3) occupancy, utilities, (4) maintenance and general expenditure for the area of the stores)]	(1) Accessibility (number of customers served divided by the population), (2) assortment (proxied by the number of stock-keeping units), (3) assurance of product delivery (transportation and security expenses, as well as card fees and bad cheque losses), (4) availability of information (number of weekly advertising fliers distributed to consumers), and (5) ambience (number of store-specific promotions)
Barros and Alves [78]	DEA-Malmquist index	47 outlets of a Portuguese hypermarket retail company: 1999–2000	(1) the number of equivalent full-time employees, (2) costs of labour, (3) number of check-out points, (4) stock and, (5) other costs	(1) Sales and (2) operating results
Barros [1]	Stochastic Cobb Douglas model	47 outlets of a Portuguese hypermarket retail company: 1999–2000	(1) Logarithm of operational cost, (2) logarithm price of labour, and (3) logarithm of price of capital.	(1) Logarithm of sales, (2) logarithm of earnings, (3) logarithm of population living within 5 min of the outlet, (4) logarithm of the area of competitors outlet within 10 min of the outlet, (5) logarithm of part-time workers in the total; (6) logarithm of average days of staff absenteeism, and (7) logarithm of the purchasing power in the area.
Barros [79]	Two stage procedure. DEA model in the first stage. Tobit model in the second stage	22 Portuguese grocery retailers. 1998–2003	(1)labour and (2) capital. Tobit model variables: (i) Herfindhal index, (ii) number of outlets, (iii) ownership, (iv) regulation, and (v) location.	(1) Sales, (2) operational results, and (3) value added.
Sellers and Mas [19]	Stochastic production function and DEA models	491 Spanish retailers, 2004	(1) Assets; (2) Capital employed; (3) investment; (4) employees; and (5) selling area.	(1) EBIT and (2) net income
Botti et al. [80]	DEA	16 Hotels	1) Costs; (2) territory coverage; and (3) chain duration.	(1) Sales

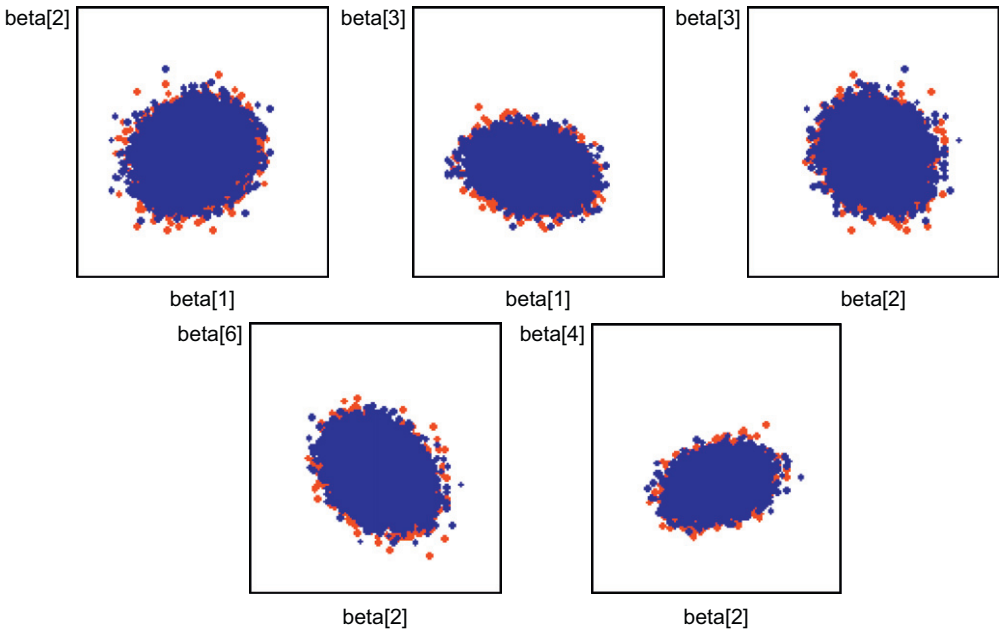

Fig. 1. Correlation matrix of some parameters of the model.

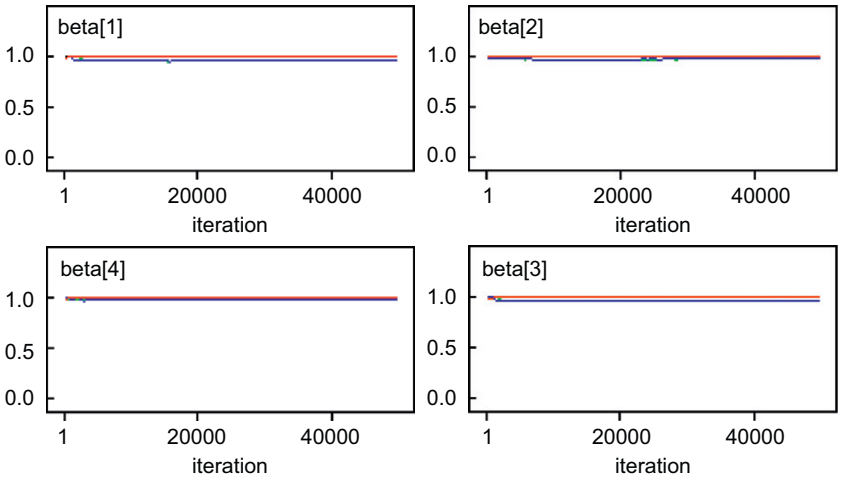

Fig. 2. BGR statistics of some parameters of the model.

Table 2
. Posterior means and standard deviations of the model parameters.

Parameter	$E(*\|\text{data})$	$D(*\|\text{data})$	Monte Carlo error
β_0	−3.3210	1.1238	0.0016
β_1	2.0781	0.2823	0.0001
β_2	0.3087	0.2796	0.0001
β_3	0.1884	0.0027	0.0008
β_4	−0.1630	0.0242	0.0002
β_5	0.3629	0.0457	0.0001
β_6	1.6242	0.1554	0.0002
β_7	−0.0112	0.0052	0.0003
β_8	−0.0821	0.0171	5.2820×10^{-6}
β_9	0.0733	0.0170	5.7630×10^{-6}
β_{10}	0.0081	0.0017	3.9920×10^{-6}
σ^2	0.5714	0.08034	3.8290×10^{-7}

than stores that do not possess these characteristics. Finally, the coefficient of the vertical integration variable is negatively signed, indicating that this strategy did not contribute to higher cost efficiency in the Spanish retail context.

Table 3
Posterior means and standard deviations of the inefficiency model parameters.

Parameter	$E(*\|\text{data})$	$D(*\|\text{data})$	Monte Carlo error
γ_1	−0.2280	0.0130	0.0125
γ_2	0.6709	0.1823	0.0150
γ_3	0.3619	0.1154	0.0009
γ_4	0.1495	0.0250	0.0082

Note: We have also checked the sensitivity of the inefficiency model parameters subject to different values of r^*. We found little variations in the values of the posterior mean parameters, and the signs of the parameters also remained consistent.

The results may be also used as external benchmarking. The process of benchmarking requires measuring the difference between the current performance level of an organization and the best possible practice. In this sense, efficiency analysis is a useful tool that can be used to identify the best possible practices that are adopted by the most efficient retailers. Equally important for managers is also the identification of factors that drive

Table 4
Posterior means of cost efficiency based on retail characteristics.

Retail characteristics	Average efficiency	St. dev
Supermarkets with vertical integration	0.6083	0.0120
Supermarkets with no vertical integration	0.6584	0.0200
Supermarkets following low price strategy	0.6940	0.0180
Supermarkets not following low price strategy	0.6114	0.0210
Supermarkets with long years in business	0.6697	0.0150
Supermarkets with short years in business	0.6393	0.0220
Supermarkets with outlets in various provinces	0.6691	0.1832
Supermarkets with outlets in one province	0.6444	0.2132

efficiency improvement. To our knowledge, this paper is the first step towards identifying the determinants of cost efficiency in the supermarket retail industry. Given the fact that supermarkets develop their activities in a very competitive environment and consumers are more demanding than ever, supermarket managers must be aware of the importance of analyzing their own efficiency, as well as how to improve it.

Actually, as the study identifies the determinants of efficiency, the results could be also of particular importance in formulating performance improvement strategies. Currently, much of the existing research analyzes efficiency at the macro (aggregate) level. Although this could be important for policy makers, it is less useful for managers who are mainly interested in the store-level performance. As the level of analysis of our research is at the micro (firm) level, the findings should provide useful implications to managers. In fact, service managers require precise measures of performance in order to draw correct conclusions about the strategies they need to outperform their competitors [64,65]. Essentially, our research aims to extend the theoretical and empirical understanding of retailing efficiency, and also provide practical implications for managers.

The generalization of our findings to the entire sector must however be done with due care, since only one of the players in the distribution channel has been analyzed, i.e. the supermarket chains. It is also worth noting that possible supply and demand restrictions derived from the scope of retail activity as a service activity have not been considered. Further, it would be possible to include other relevant variables in the production process, such as the degree of technological development of the companies themselves, as efficiency drivers. Although this paper considers several variables affecting efficiency, we should take into account that these variables are not the only drivers of efficiency.

Future research can extend the results of this study by comparing the performance of retailers across various industries (department stores, fast-food restaurants, banks, etc.). It is also possible to provide further validation to the hypotheses tested in this study by replicating the model to other countries. Depending on the data availability, it is also possible to test the impact of other retails store characteristics on efficiency. For managerial purposes, it might be also useful to conduct some detailed case analysis on inefficient and efficient stores in order to identify other best practices that can help improve the performance of low performing stores.

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