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Product innovation in the Spanish auto market: Frontier shift and catching-up effects

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ABSTRACT

This paper investigates how product innovation and competition dynamics have driven the evolution of product efficiency in the Spanish auto market. We have collected data on more than 75 technical product features and discounted prices for a representative sample of car models commercialized within a 5-year period (2010–2015). Product efficiency is measured for each period by means of Data Envelopment Analysis (DEA). This technique identifies a best-buy technological frontier by comparing the price and product features of the different models. Furthermore, we track the dynamic evolution of product efficiency by computing and decomposing Malmquist indexes measuring the overall improvement in the car models analyzed. The decomposition of the Malmquist index brings new insights to the assessment of product innovation. First, the frontier shift indicates how much each model should have improved to simply maintain its comparative competitive appeal. Second, the catching-up effect indicates whether a model is getting closer to or farther away from the new (shifted) best-buy frontier. In the period analyzed we find important improvements in product features that were accompanied by price cutting. Both factors have contributed to significantly expand the best-buy frontier outwards. Audi, Volkswagen, Honda, BMW, Kia, Hyundai, Peugeot, Renault and Seat are identified as the brands that have contributed more to expand this frontier. In turn, Renault, Peugeot and Seat show the largest catching-up effects.

1. Introduction

Lancaster's (1966) seminal work described a product as a bundle of attributes, which implicitly determine the value of the product as a whole (Cross et al., 2013). Since then, a growing body of research has tried to estimate product/price ratios by comparing attribute levels and prices of competing products. From such comparisons, *Best-buys* can be represented on a consumption frontier and then product efficiency can be estimated as the distance of a product to the frontier in the attributes/price space. Measured this way, product efficiency is a measure of the value received for the money paid (Bauer et al., 2002; Smirlis et al., 2004), being a central research interest in business strategy and marketing (Zeithaml, 1988; Dodds et al., 1991; Holbrook, 1994).

Data Envelopment Analysis (DEA) is a powerful tool for the empirical construction of frontiers. In the field of product efficiency estimation, it was first proposed by Kamakura et al. (1988), who adapted the technique for the measurement of pro-

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duct efficiency in various different markets, including automobiles. After this pioneering work, many authors have applied DEA to estimate product efficiency in different sectors, such as computer printers (Doyle and Green, 1991), notebooks (Fernández-Castro and Smith, 1996), numerical control machines (Sun, 2002), mobile phones (Smirlis et al., 2004; Lee et al., 2005), computer printers (Seiford and Zhu, 2003), digital cameras (Chumpitaz et al., 2010) and, most notably, automobiles. To the best of our knowledge, the DEA approach has been applied to evaluate the product efficiency of automobiles by Papachristodoulou (1997), Papagapiou et al. (1997), Bauer et al. (2002), Fernández-Castro and Doldán (2002), Fernández-Castro and Smith (2002), Staat and Hammerschmidt (2005), Choi and Oh (2010), Oh et al. (2010), and Hwang et al. (2013). More recently, González et al. (2013, 2015) have also applied these methods to explore product efficiency in the Spanish auto market and the dynamics of price discounts at the dealership level.

In this paper, we extend the González et al. (2015) database to analyze the dynamic evolution of product efficiency within the Spanish auto market over a five year period. We track the changes in both car attributes and prices introduced by different manufacturers in their products between 2010 and 2015. Technological innovation is fast within this industry and, as a consequence, car buyers expect to find models including improved attributes and recent innovations at lower (discounted) prices year by year. We compute and decompose Malmquist indexes (Caves et al., 1982), to assess the extent to which the models in the sample have improved or worsened during the period in terms of product/price relation. The expectation is that most models have improved over time, to match the expectations of consumers in the market. Innovation (and competition dynamics) should foster the introduction of improvements in car attributes at similar or even lower prices. For instance, while only a few car models included electronic stability control as part of their standard equipment some years ago, it is included as a standard feature in most models today without any price supplement.

After estimating the Malmquist index, we will proceed to decompose it into its two basic components, namely, the frontier shift and the catching-up effect. An outward frontier shift will be observed if the best-buys are dynamically offering more for less (an inward frontier shift if the opposite occurs). Technological progress should translate into outward shifts of the best-buy frontier and, therefore, this is the expected result. On the other hand, all car models should evolve at the same pace if they want to maintain their initial market appeal. But, in practice, some models will move more rapidly than others through the attributes/price space. The second component of the Malmquist index (catching-up) will measure these movements, showing whether a specific car model is dynamically getting closer to the frontier or is falling apart, thus gaining or losing competitive appeal.

Although we are aware of many papers measuring product efficiency, we are only aware of one that includes a measurement of the Malmquist index (Fernández-Castro and Doldán, 2002), but does not include a decomposition of the index. More recently, Chumpitaz et al. (2010) estimated the Luenberger indicator (which is related to the Malmquist index) in the context of product efficiency. In this paper our objective is to make an empirical contribution to this literature. We have collected a very complete data set that avoids some of the limitations of previous research. First, past research only accounted for dynamic changes in prices, but not in product features. In this paper, we consider both sources of product evolution. Second, previous research relied on list prices, which are markedly different from real market prices in the automobile market. In this paper we have compiled data on real discount prices actually set by dealerships in the marketplace. Third, previous research focused on a very narrow part of the market, including a reduced number of models and versions. While we will limit our analysis to only one segment of the market (compact cars or C-segment), we have collected data on all the models which are offered within this segment in Spain. Using a large sample is essential in order to provide an accurate approximation of the real underlying frontier when using non-parametric tools such as DEA. Fourth, the number of car attributes studied in previous research is too narrow and limited to the most obvious car features. In this paper, we combine information on more than 75 attributes which account for most of the car features that consumers are able to evaluate when facing a car purchasing decision.

In order to achieve these goals, the paper builds on the previous research carried out by González et al. (2013, 2015) who measured product efficiency in the Spanish auto market with discount price data from 2010. This paper focuses on the segment of "compact cars" and extends the analysis to year 2015. We concentrate on the compact cars segment, because it is the most popular segment of the market (25% of sales in 2015). Of the original 2010 models, some were replaced by completely new models while others have evolved through different restylings and updates. These innovations can be interpreted as competitive movements that shift the frontier and also generate catching-up movements.

2. Methods

Our objective is to construct an empirical *best-buy* frontier by applying DEA and to track the movement of that frontier as product innovations unfold over time.[1] A product will be considered as a bundle of attributes and the products will be compared on the basis of the value of these attributes. In order to adapt the comparison to the DEA methodology, each attribute can be characterized either as an input or an output. Inputs are car features that customers would like to minimize (e.g., price, fuel consumption, etc.), while outputs are the features that customers want to maximize (e.g., horse power, equipment, etc.). The consideration of a variable as an input or an output may sometimes be arbitrary. For instance, fuel consumption can be mea-

[1] A recent review of the issues to take into account when performing a DEA analysis can be found in Cook et al. (2014). A different but related (parametric) approach is the estimation of stochastic frontiers (see Álvarez and Arias, 2014 for a recent overview).