

**THE CAUSAL EFFECTS OF PRODUCT INNOVATION, WEB TECHNOLOGY AND VERTICAL  
INTEGRATION ON FIRM EFFICIENCY IN THE FASHION INDUSTRY**

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**Abstract**

This paper examines the interaction among product innovation, web technology and vertical integration, and their effects on firm efficiency in the fashion industry. One contribution of this work is that we do not assume the effect of these variables on firm efficiency to be monotonic. Additionally, rather than using standard financial ratios, we use the Data Envelopment Analysis (DEA) methodology to measure efficiency. Our results indicate that product innovation has a monotonic and positive effect on efficiency. On the contrary, web technology, as a process innovation, does not always positively affect firm efficiency: it exerts a negative effect during the first stages of the technology implementation, and then it becomes positive when the implementation is more advanced. On the other hand, web technology moderates positively the effect that vertical integration has on efficiency.

**Keywords:** product innovation, process innovation, web technology, vertical integration, innovation, efficiency, data envelopment analysis.

## 1. Introduction

Innovation has become essential to firms seeking to gain a better position: new products and services are constantly emerging, and process innovations have transformed the traditional ways of doing business. As Markides (1997) states, strategic-innovative firms have redefined the who, the what and the how of their firms' by thinking about new customers or new customer segments as well as products and services. In recent years, there is a sector that has experienced these changes in a more intensive way: the fashion industry. Innovation activities are more likely in creative industries, like fashion, than in other sectors (Bakhshi and McVittie, 2009). The use of new technologies, product development and new business models has become essential in this sector. In an environment of structural changes, some firms operating in the fashion industry have taken advantage of these new business models and have attained great business success as a result. These firms have generated new structures that have improved over time through the incorporation of different innovations. The use of IT has generally transformed the way that firms in this sector are managed as well as their results (Institut Français de la Mode, 2004; Mcaffee, 2004; The Economist, 2005). Innovative firms have increased their selection of new designs and moved away from traditional sales and marketing methods. They combined their distribution networks with the manufacturing process to allow the rapid introduction of new products. For example, Inditex has generated new processes by combining Information Technology (IT) with new operationally integrated systems and vertical integration that have reduced cost and delivery time response.

Although very good research can be found in the literature on the relationship between innovation adoption and performance, e.g. Alpay et al., (2012); Bunduchi, Weisshaar, and Smart, (2011); Fryer and Versteeg, (2008); Liu and Wu, (2011), it is hard to find papers in the literature that simultaneously consider the relationship between product innovation and web technology adoption together with the relationship with other strategic decision like vertical integration. This is an important issue as the exclusion of some of these variables may result in misleading conclusions about the effect of

innovation on performance. Furthermore, not taking into account the interaction among some of these variables may distort results. Our first contribution to the literature on innovation tries to fill this gap. Our second contribution to the innovation literature is related to the effect that innovations exert on performance. We avoid the assumption of linear effects by including second-order terms. This allows the the estimated function to have a u-shape so that it can be increasing for the first stages of the development of the innovation and decreasing afterwards (or vice versa). It is important to consider that some types of innovations, such as process innovation, may be time consuming and present a high level of expenses in the first stages, so that they may have a negative effect on performance in the short term but a positive effect afterwards. Kleinschmidt and Cooper (1991) proved that innovativeness had a u-shape relationship with performance, so that low and high innovativeness were more likely to be more successful than intermediate levels.

We have used data envelopment analysis (DEA). DEA is a linear programming technique for measuring the relative performance of business units. Although it is based on linear programming techniques, the efficient frontier is not linear. While the use of DEA to measure efficiency is not a contribution per se, but it is a better measure to estimate efficiency than simple financial ratios and DEA is not very much used in the innovation literature. Furthermore, literature often identifies performance with efficiency (Murthia et al., 1997, Chang and Lo, 2005, Gerard George, Zahra and Wood, 2002). We think DEA has some advantages. For example, other performance measures like financial ratios consider only two financial variables and they may represent the problem that different ratios can provide different performance values. DEA has the advantage over other efficiency measures that it can include several inputs and several outputs to produce an overall measure of performance for each unit analysed.

Therefore, this work provides a more integrative model, achieving a better understanding of the innovation phenomena through Data Envelopment Analysis and an exploration of the causal relationship between firm efficiency, product innovation, web technology and vertical integration. Like other studies on innovation (Hysalo, 2009; Lim, Garnsey & Gregory 2006), our research is based on the innovation analysis of a

specific sector, namely, the fashion industry, with the objective to control for industry-level differences.

This paper is organised as follows. The next section presents the conceptual background and hypotheses. Then, we describe the methodology and data analysis, present the results and discuss them. Finally, we address some conclusions.

## **2. Background**

Innovation can be defined as the application of new ideas and knowledge to new products, services and processes. Innovation can imply changes in products, technology or different firms' configurations that affect the way things are being done and how clients are served. Innovation is considered a driving force of competition for the success of firms (Cardozo et al., 1993; Frambach & Schillewaert, 2002) and a source of competitive advantage (Marsili & Salter, 2006), and its intensity and significance differ according to industry (Tether, 2005), culture (Pohlmann, 2005), region (Kale & Little, 2007), environment (Elenkov et al. 2005) and institutional ties (Ranga, Miedema & Jorna, 2008). Like other business factors, innovation is affected by globalisation, which is transforming the environment, making it more competitive. In this context, revolutionary, innovative international firms may reap the benefits of these changes not only by creating new products but also by adopting externally developed innovations.

Although innovation is, in general, associated with higher firm performance, the lack of a direct connection between innovation and performance probably reflects the fact that the profitability of innovation largely depends on other factors. These factors can include the competition within each sector, information asymmetries, life cycle, a strong initial investment in technology, new product and production facilities, vertical integration and, of course, the different types of innovations that are being used. Innovations are frequently interconnected because product innovation may at times require some types of process innovation to result in success. For example, new processes and new strategies are needed for incremental product innovation or new processes may be needed to develop services innovation. Process innovation allow innovators to scale up their business models quickly, thus protecting themselves from competition (Markides & Anderson, 2006). Process innovation, as a facilitator of product innovation, may represent an important source of new information for firms.

For example, web technology can be used to get more information in real time about the customers' preferences, which may affect product innovation.

Innovation is not only important for emerging sectors, such as the biotechnological. It is also present in other mature sectors such as the fashion or automobile sectors, in which opportunities to innovate include the development of new products and markets and technological changes.

### *2.1. Web technology adoption as a type of process innovation?*

Process innovation is considered a relatively non-discrete and non-sequential stream of activities (Kessler & Chakrabarti, 1996). The concept of process innovation describes how firms change the ways they operate. These changes are difficult to carry out, and because of that, the costs of implementing process innovations are generally higher than those of implementing product innovations (Gopalakrishnan & Bierly, 2001). These higher costs come from coordinating, training and educating personnel activities as well as from difficulties in learning transfers and codifications generated by complexities within the organisation (Gopalakrishnan & Bierly, 2001).

One of the most important aspects of process innovations is that they enable firms to reach consumers that most competitors cannot serve in a profitable way (Fryer & Versteeg, 2008). More specifically, this is done by offering radically new value to consumers that other firms cannot deliver in a cost-efficient way and by putting value mechanisms into place that other firms cannot establish efficiently. Furthermore, web technology as process innovation may lead to improvements in efficiency, reducing development costs. However, as we mentioned before, this imply high expenses over the period of implementation.

Web technology may lead to better performance through cost reductions and product quality improvements (Liu & Wu, 2011). As a sector evolves towards maturity, continuous innovation must coexist with a strong degree of pressure encouraging cost efficiency (Lim, Garnsey & Gregory 2006). It is easy to identify successful process innovations that have increased a company's efficiency, and an important line of research deals with the impact that process innovations may have on firm efficiency (Dewett & Jones, 2001; McFarlan, 1984; Porter, 1985; Porter & Millar, 1985; Rayport & Sviokla, 1995).

Web technology can contribute to a reduction in operational costs in various ways. It can add to disintermediating relationships with customers and provide a more direct link between the customer and the firm by simplifying the ordering process (Zhuang & Lederer, 2003). Innovative technologies can integrate customers' information systems, achieving a higher degree of inter-organisational agility, fostering flexible working practices and reducing labour costs (Piris et al., 2004).

Some process innovations, like web technology, can also be related to a decrease in internal transaction costs (Santarelli & D'Altri, 2003), by improving information management, by facilitating negotiation or by establishing more efficient ways of enforcing contracts in the context of internal transactions. Also, they can reduce internal costs indirectly, allowing firms to participate in inter-organisational networks. When internal transaction costs are reduced, efficiency can be related to higher overall performance.

Nevertheless, because innovation costs and benefits vary as a technology evolves (Bunduchi et al, 2011), web technology may not positively affect efficiency in the short term, and in fact they could have a negative effect during the first stages of the implementation for several reasons. First, the positive effects of technology adoption on intermediate resources such as skills, image and satisfaction to mature may take some time to appear. Second, new technologies generally imply high investments, which require a greater period of time to pay back their value to the firm.

The above reasoning leads us to propose the next hypothesis:

*H1: Web technology positively affects firm performance, although it negatively affects performance during the first stages of the implementation.*

## *2.2. Product innovation*

As a result of the global standardisation of products, product innovations including additional services, are increasingly important tools that can give firms the opportunity to gain a better performance (Cooper, 1984; McColl-Kennedy & Schneider, 2000). The launch of new products may positively affect efficiency if competitors cannot easily and rapidly copy a product innovation. Therefore, by protecting new products against imitation, profitability may be higher and may last a long time; otherwise, revenues will be scarce and will not be long-lasting.

Product innovation may lead to a high profitability because it promotes the development of other intangible resources. The impact that innovation has on other necessary resources is a crucial element of the relationship between innovation and performance because the success of innovation may depend on these resources, which include customer satisfaction and image. Customer satisfaction contributes to a firm's competitive advantage (e.g., Anderson, Fornell, & Lehmann, 1994; Edvardsson, Johnson, Gustafsson, & Strandvik, 2000; Eklof & Westlund, 1998; Srivastava, Fahey, & Christensen, 2001) and improves its performance (Gomez, McLaughlin, & Wittink, 2004; Hooley, Greenley, Cadogan, & Fahy, 2005). Empirical studies have demonstrated that firms with a high degree of customer satisfaction have better economic returns and market value (Anderson et al., 1994; Edvardsson et al., 2000; Eklof & Westlund, 1998). Customer satisfaction can directly affect firm's efficiency by increasing revenues (Edvardsson et al., 2000). New customers can be reached by the recommendations of previous customers with positive experiences.

In the fashion industry, the product life cycle is very short. Firms sometimes change their collections four or five times a year, and sales depend on new product development and the speed with which these products are brought to stores. Thus, organisations must be aware of new customers' preferences and trends, paying greater attention to improving their collections and bringing the new products to the market.

This discussion leads us to formulate the following hypothesis:

*H2: Product innovation positively affects firm performance.*

*2.3. Vertical integration* One key element of innovative firms is the managers' capacity to view the industry and the company in a new light (Jacobs & Heracleous, 2005; Markides, 1997). Innovative strategies imply new forms of competition in a sector and new ways of doing business, such as vertical integration. Vertical integration is the degree to which a firm owns its upstream suppliers and its downstream buyers (Grant, 2005) and it affect firms' innovativeness (Mazzanti, Montresor, and Pini, 2007). Although networking effects coming from outsourcing activities are usually retained important for a product kind of innovation, vertical integration strategies could be more effective because of the external suppliers' difficulties to understand the viability of innovation activities (Mazzanti, Montresor, and Pini, 2007). Outsourcing could hamper

the strict coordination and the numerous information flows necessary to undertake properly innovative activities (Mazzanti, Montresor, and Pini, 2007).

The success of vertical integration strategies also depend on the kind of technological change and on the sector it takes place in (Mazzanti, Montresor, and Pini, 2007) In young sectors, product innovation is a key source of competitive advantage, but in mature sectors other sources are needed to compete because the rates of product and process innovation are generally modest in these sectors. The strong competition and the limits on opportunities to establish and maintain competitive advantages are the triggers that create the impetus for changes in marketing, client services and organisation. These changes not only create competitive advantages but also provide the basis for eliminating the competitive advantages of other companies. Firm's degree of vertical integration may affect performance directly and indirectly because vertical integration affects the way that resources and capacities are managed to gain competitive advantage. Activities such as production, marketing, distribution and financing usually require integrative strategies and different forms of business organisation for a firm to attain better performance. By combining distribution with manufacture firms may promote market expansion and growth (Song & Zahedi, 2006).

The fashion sector model is characterised by a high degree of integration compared with other models developed by other sectors. Leading a management model based on innovation and flexibility has resulted in rapid international expansion and excellent performance. Firms in our dataset that integrate vertically, design the frames to their own specifications, as design capabilities comprise a key source of differentiation among fashion firms. The integration of activities such as design, production, logistics and sales, which take place in the company's own stores, has made these firms flexible and fast in adapting to the market. Their business model is characterised by continuous product renovation, in which new products reach the stores twice a week. The key advantage of this model is the ability to adapt the product offering to changing customer desires in the shortest time possible.

In general, this new business model enables fashion firms to shorten turnaround times and to achieve greater flexibility, reducing stock to a minimum and diminishing the risk of producing unfashionable items as much as possible. Also, it enables firms to

recognise and assimilate the continuous changes in fashion, constantly designing new products that respond to customer desires. Firms use its flexible business model to adapt to changes occurring during a season, reacting to them by bringing new products into stores in the shortest possible period of time. Selling is not the end of the process, because the stores, by means of new processes, gather market information, providing feedback to the design teams and reporting the trends in customer demand.

Nevertheless, firms that are more vertically integrated may lose scale advantages and may be forced to manage more complex routines because of their product line broadens (Randall & Ulrich, 2001), indicating that manufacturers might have more difficulty managing broad innovative product lines than firms that are less vertically integrated.

However, we assume that the positive effects associated to vertical integration, surpass the negative ones. Therefore we propose the following hypothesis:

*H3: Vertical integration has a positive effect on firm performance.*

#### *2.4. Web technology: Implications derived from the relationship with vertical integration.*

The impact that vertical integration has on firm performance can be increased through web technology. Web technology is able to create internal networking effects. Web technology can be able to create an appreciable diversity in information, and possibly stimulate innovating internal flowing effects down-up coming from employees, which can contribute to increase product innovation activity. Also, thanks to the combination of vertical integration and web technology in e-commerce activities, firms can expand their activities without having a physical presence in the markets (Chaudhury et al., 2001). In this way, web technology may help with aspects such as attracting new customers, the creation of new distribution channels, adding value to services for customers, reaching new markets and enhancing corporate image. When employing internationalisation strategies, firms can use new technologies, like a webpage, as a means of collecting information about international customers, allowing the building of data warehouses and data mining. New technologies can also provide new business opportunities in the home country, altering traditional organisational constraints related to geographical distance and unlocking new economies of scale and scope (Rayport & Sviokla, 1995).

*H3a: Web technology positively moderates the effect of vertical integration on efficiency.*

*Research model:*

*Insert Figure X about here*

### **3. METHOD**

#### *3.1. The industry*

The sample for this study is composed of firms operating in the Spanish fashion industry. The fashion industry is a part of the textile and apparel industry. The centers of the fashion industry are Europe and the United States with famous brands, such as Giorgio Armani, Chanel or Dior located in cities such as Milan, Paris, and New York. However there is also a large number of firms participating in this market who are looking for other ways to compete (Salmeron and Hurtado, 2006).

Spain accounts for 6.2% of the European apparel retail industry value (Datamonitor, 2010). Although traditionally the core product of the fashion world was clothes, nowadays the product portfolio has been extended notably to other goods, such as jewellery, perfumes, watches, handbags, hats, eyewear, footwear and belts. Some of these products can be commercialised on the internet; others such as clothing may be difficult because their processes of commercialisation and distribution are more complex. Nevertheless, in recent years the fashion industry has undertaken important and profound changes investing in web technology. Web site and B2C activities represent an advantageous mean of marketing for the firms. The use of web technology has been revealed as a good mean for companies to display their latest fashion line and products, allowing the business to target customers all over the world in a less expensive way than through opening new stores (Salmeron & Hurtado, 2006). For example, the most representative Spanish firm, Inditex, said it will accelerate expansion online. This is a key piece of strategy, suggesting e-commerce at Zara is going well. The brand is available online in 16 countries and Inditex plans to expand coverage to other countries. It also introduced online shopping for brands other than Zara in the second half of 2011. *3.2 Sample and data collection*

Firm data were obtained from the Bureau van Dijk Electronic Publishing database, which provides information about firms operating in the textile and fashion

industry according to the European Classification of Economic Activities. A filtering process was conducted by checking the firms. The process was made by the analysts. To ensure that all the firms that we added to the database were all operating in the fashion sector, we checked and carefully peered one by one at each of the firm's webpages to confirm that their activities could be classified in the fashion industry. The resulting population was 1,106 firms. The introductory letter asking for collaboration outlined the objectives of our research and our contribution to the sector. We offered participants the possibility of answering the questionnaire either by post or via a web-based survey.

In order to ensure that the questionnaire collected adequate information, it was reviewed by managers of several sample firms before the definitive mailing. Their comments and proposals were taken into account in the final version.

Of the 1,106 questionnaires sent by post, 84 were returned due to problems with addresses. Following a previous methodology (e.g., Powell & Dent-Micallef, 1997), we used at least one phone call as a follow-up method to correct problems related to the questionnaire and to increase the overall response rate. Once that stage was complete, we had a total of 136 questionnaires, which represents a response rate of 12.3%. We are aware that this response rate is low due to problems associated with the geographical dispersion of the fashion industry population and due to the fact that the research was being conducted at the organisational level and a single sector. Even so, our response rate is comparable to that of other studies using similar methods (Cooper *et al.*, 2005). Nevertheless, in order to reduce this problem, we provide a supplemental analysis to confirm that the sample represented the whole population: the results using a one-sample *t* test suggested that the distribution of firm sizes in the sample did not significantly differ from the distribution in the whole firm population.

### 3.3. Measures

#### 3.3.1. Dependent Variable: Firm Performance

Performance is measured in very different ways in the literature. Very commonly, authors use subjective measures of performance (e.g. Roger, Kwong & Anna, 2006) whereas others use simple financial ratios (e.g Hertenstein, Platt & Veryzer, 2005). However, there is a wide literature that presents several approaches to formally measure

firm efficiency (Herrero, 2005), though it is mostly applied in economic studies. These formal techniques can be classified as parametric or non-parametric. This study adopts a nonparametric method to estimate technical efficiency: the Data Envelopment Analysis technique (DEA). Although DEA is a useful methodology and is commonly used in economic studies, it has not been widely used in the innovation literature.

One of the main advantages of DEA is that the frontier is not restricted by any functional form, as is the case with other efficiency techniques. The technique is based on the observations in the sample, and with some of them, an efficient frontier can be constructed. DEA considers all units under the frontier to be inefficient.

In our case, we are interested in the output-oriented model, because we are more interested in firms' maximising their outputs than we are in their minimising their inputs.

Figure 1 presents a simple example of an output-oriented model with one input and one output. Points A, B, C, and D are efficient and determine the frontier. All additional observations lie below the frontier. The frontier represents the maximum output that could be achieved given a certain level of inputs. Note that the rest of the points observed could be using the same level of resources to produce a higher amount of output than they actually do. For example, in Figure 1, unit E is inefficient, because unit E' uses the same level of input as unit E but produces a higher amount of output. The distance from each observation to the frontier is an indicator of the level of inefficiency of the unit. The inefficiency rate of unit E is given by the ratio  $E'E/E E'$ .

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Insert Figure 1 about here

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It is important to point out that efficiency is a *relative concept*. The efficiency rate of a given firm depends on the group of observations with which we are comparing it.

We used a Banker, Charnes and Cooper (1984) DEA model that does not impose any assumption regarding the returns to scale of the production process:

Maximise  $\theta_{j_0}$

subject to:

$$x_{i,j_0} \geq \sum_{j=1}^J \lambda_j x_{i,j_0}, \text{ where } i = \text{total assets and no. of employees}$$

$$\sum_{j=1}^J \lambda_j y_j \geq \theta_{j_0} y_{j_0}$$

$$\sum_{j=1}^J \lambda_j = 1$$

$$\lambda_j \geq 0, \quad j = 1, \dots, J,$$

where  $Y_j$  represents the sales of firm  $j$  and  $X_{j,i}$  corresponds to the amount of the  $i^{\text{th}}$  input ( $i = \text{total assets and number of employees}$ ) used by firm  $j$ . The zero sub-index stands for the unit being analysed. Note that this model has to be solved  $J$  times (i.e., once for each observation). The inefficiency rate associated with the unit being analysed is given by the inverse value of theta:  $TE_{j_0} = 1/\theta_{j_0}$ . Firm efficiency is given by the inverse of theta. TE is bounded from above by 1 and from below by 0. If TE is equal to 1, the firm is fully efficient if it is less than 1, then it is inefficient.

A DEA model allows for the inclusion of multiple inputs and multiple outputs. In this work two inputs were considered: the number of employees (representing human resources) and total assets (representing capital invested). Our model only had one output because of data availability, and it used the volume of sales as the output. We chose sales as the output rather than benefits for several reasons. On the one hand, sales are more commonly used as output in the literature (Cooper et al., 2000). On the other hand, the benefits of some firms took on negative values, and the DEA technique does not allow zero or negative output values. This disadvantage is addressed in the literature by translating the data; however, the output-oriented model is invariant to translation in inputs but is not invariant to the translation of outputs, reason for which sales was preferred as output.

While the information we had available on the integration process and the product innovation and web technology carried out by the firms were referred to years

2003, 2004 and 2005, all the variables related to efficiency were referred to year 2006. By doing this we expected to capture the effect of the innovations and the effect of the integration process over several years on the performance of a subsequent year.

### 3.3.2 Independent Variables

**Web technology** was measured according to the level of web technology adoption of the firm. This variable (Aragon-Correa & Cordón-Pozo, 2005) may affect information-intensive business processes (Chatterjee *et al.*, 2002), because they have different uses and different potential levels of use, ranging from a web site that provides very simple information to integrated infrastructures that provide support for different firm activities. For example, web activities can directly affect and improve internal performance in areas such as the packaging and delivery process, the reduction of stock, fixed costs and global assets. Chatterjee *et al.* (2002) suggested that the use of web technology had two different implications for performance. First, the direct operational implications involve a cost reduction. Second, there are other implications derived from the relationship with vertical integration.

We adapted and used a scale validated by Teo and Pian (2004) to measure the level of adoption of web technology. We asked respondents to rate the level of adoption of Web technology that most closely fit their firms (one of five levels of adoption of Web technology presented in the questionnaire). Each level was described at the beginning of the questionnaire according to the classification by Teo and Pian (2004), and the respondents were asked to classify their firm as belonging to one of the five levels. The first level is for those firms that only use an e-mail account. The second level includes the use of a web-site providing very simple information. The third level involves a web site that provides extensive information regarding the firm and its products, including a feedback form, e-mail support, and simple searching. The fourth level includes advanced features such as interactive marketing and sales, online communities, secure online ordering, support for business activities and cost reduction. Finally, the fifth level implies a cross-enterprise type of involvement, with the focus on building relationships and developing knowledge to create new business opportunities. In this latter case, the firm is electronically integrated with its key suppliers and customers for procurement and/or supply chain activities. Additionally, we asked the firm to indicate the date of

implementation of the first level of web technology. To test hypothesis 1, we took into account a second order term for web technology.

To measure **product innovation**, we asked the respondents to indicate the number of new products developed by their firms in the years 2003, 2004 and 2005. The respondents indicated the number of new products that during the years the firm has achieved: products that were completely new or with modifications significant enough to make them different from the ones that the firm was producing previously.

To measure **vertical integration**, we used a proxy by asking the respondents what proportion of the firm turnover was sold by using their own channel of sales (own stores and e-commerce) in years 2003, 2004 and 2005.

#### 4. Results

The efficiency model was programmed in GAMS, a multi-purpose software package that is mainly used for linear and nonlinear optimisation techniques from which we got the efficiency measures that were subsequently used in a regression analysis.

The average efficiency rate of the firms (Table 1) is reasonably high (0.68), with a standard deviation of 0.25. The minimum estimated value of technical inefficiency is 0.22, and the maximum value is 1 (full efficiency).

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Insert Table 1 about here

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To examine the relationship between the independent variables and firm's efficiency, we carried out a step-wise regression analysis with the (standardized) efficiency rates as the dependent variable. This regression did not assume linearity between the variables and firm performance. The first-order terms associated with the three variables and two second-order terms associated with web technology adoption and vertical integration were included to allow these variables to take on a parabolic relationship (U-shaped) with firm efficiency rather than restricting them to a monotonic relationship. We also

included the cross-product term of web technology and vertical integration to check for a moderating effect of the former on the latter.

Some of the correlations among the variables were significantly different from zero (Table 1). To ensure that multicollinearity was not an issue, we computed Value Inflation Factors (VIFs), but none reached values above 3. Analogously the condition indexes were all far away from limit levels, indicating the absence of multicollinearity.

Therefore we regressed the normalised measures of performance on the (standardised) measures of three independent variables: product innovation, web technology and vertical integration. We also included second-order terms for product innovation, web technology and vertical integration to allow a more flexible functional form rather than imposing linearity on the relationships. This implies that we are not imposing the idea that the effect of the innovations on performance has to be positive or negative (monotonic behaviour). Their effect may change with their levels, having a negative effect for low levels of innovation and a positive effect for higher levels (or vice versa). Furthermore, we included the cross product between vertical integration and web technology to test for the moderating effect of web technology on vertical integration.

The results for the non-linear hierarchical regression analysis among key variables and efficiency are presented in Table 2. Product innovation and the second-order term of web technology were significant in the regression results. However, although the coefficient associated with vertical integration was not significant when included in the regression, the moderation effect of web technology on the effect of vertical integration on performance was significant and positive. From these results, we can conclude that vertical integration, does not affect performance unless the firm uses web technology (at any level). Therefore, process innovation (measured as web technology adoption) is a key element to consider in pursuing the success of vertical integration and its effect on performance.

The squared term of web technology has a positive coefficient, implying that the relationship is not linear. Furthermore, the positive sign associated with the squared term of web technology suggests a concave upward relationship between web technology and performance. We suggest that for lower or intermediate levels of web

use, the effect on performance is negative, whereas performance increases for intermediate or higher levels of technology adoption, until it reaches a level where its effect on performance is positive<sup>1</sup>. We analysed the effect on performance by taking the first partial derivative with respect to the variable web technology and setting it equal to zero. The minimum value for this function was for a level of web technology equal to 2 (Figure 3). Therefore, the firm performance decreases when web technology adoption is in its initial stages (for the first and second level), whereas it increases when web technology adoption is more advanced (at the third level and higher), resulting in a U-shape graph.

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Insert Figure 3 about here

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Furthermore, the parabolic function suggests that the higher the level of information technology adoption, the higher is its effect on performance (because the curve is steeper, and the second derivative is positive). Therefore, although this study uses cross-sectional data, because the levels of technology adoption are discrete it is possible to draw some conclusions about the effect of technology adoption over time. We can conclude that the longer a firm has been using new technologies, the higher the level of information technology adoption they have reached. Web technology is a type of innovation in which firms progressively adapt in a few steps. Therefore, we can conclude from the results that when the firm is at the initial stages of web technology (during the first steps), the effect on efficiency is negative.

Then, as the firm progressively reaches higher (third and following) technology levels (later in time), the firm becomes more efficient. This is why even without time series data on web adoption, which we did not have available because the last steps in the adoption process cannot be done without finalising the first steps, our conclusions can be drawn over time. Firms in the first stages perform at a lower level than those that do

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<sup>1</sup> Note that the form of this function is a concave upward parabola; therefore, it has a minimum.

not use any web technology, whereas firms with higher levels of web-technology adoption are better performers than those that have not adopted any web technology.

As previously noted, the coefficient associated with the interaction between web technology and vertical integration was significant at the 10% level, confirming Hypothesis 3, that web technology moderates the relationship between vertical integration and efficiency.

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Insert Table 2 about here

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We graphed the interaction effect (Figure 4). We considered the mean +/- 1 standard deviation as high/low values of a variable. From the interaction term of the two variables, we can conclude that for low levels of web technology adoption, firms that are low vertically integrated are more efficient than firms more integrated. On the contrary for high levels of web technology adoption, efficiency increases the higher the level of vertical integration.

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Insert Figure 4 about here

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## 5. Discussion and Conclusion

This paper corroborates the results of previous works (Li & Tang, 2010) suggesting that links exist between innovation activity, vertical integration and firm performance without imposing linear effects. This is an important contribution because linear effects are imposed in most management studies. The use of formal measures of efficiency such as the DEA is also still quite novel in innovation studies.

The results of our analysis show what we intuitively expected: firm performance is affected by product innovation and web technology, and web technology moderates the effect that vertical integration has on business performance. However, we have found that vertical integration does not in itself exert any effect on performance unless

the firm uses high levels of IT. Therefore, process innovation, measured as the adoption of web technology, is a key element for the success or failure of vertical integration and its effect on firm's efficiency. From the results, we conclude that web technology exert a positive effect for highly integrated firms, whereas the reverse occurs for firms that are not vertically integrated (Figure 4). JOSE MAUEL ¿PUEDES COMENTAR ALGO MAS AQUI E INCLUIR ALGUNA REF?

The use of non-linear effects led us to conclude that the effect of web technology on performance is not positive for all levels of web technology. The results show that firm's efficiency decreases when process innovation (web technology adoption) is at its initial stages (at the first and second levels), whereas it increases when web technology is more advanced (at the third level or higher). The decrease in performance associated with web technology during the initial stages of adoption can be explained using the Resource-Based View: investing in technologies may not positively affect performance in the short term. Furthermore, our results suggest that the influence on performance could be negative in the short term. We suggest that there are two main reasons that explain this result: the initial investments and the adaptation costs. Also, adaptation to the new technology may be time consuming for employees. Therefore, even if an adequate synchrony between traditional activities and the new web-based activities that are supported by web technology can lead to an increase in efficiency, a high level of web adoption may imply a strong investment. This may eventually have a negative effect on profitability in the short and medium term but it pays off in the long term.

On the other hand, web technology, as a process innovation, consist of assets such as mainframes, computers, software and physical locations, which tend to depreciate quickly, becoming obsolete in a short period of time. These can then turn into liabilities instead of assets (Porter, 1991; Porter, 2001).

Regarding product innovation, we can conclude that the higher the level of product innovation, the higher the performance of the firm for all levels of product innovation. To summarise, by vertical integration, we do not mean the simple integration of closely related production activities. Rather, we mean the integration of activities that belong to distinctly identifiable separate industries. In a world with no transaction costs, vertical integration could be intrinsically inefficient because it would reduce specialization and

thus the exercise of comparative advantage among firm units. However, in fact transactions between separate units may have transaction difficulties. If these transaction difficulties cannot be overcome, vertical integration can be a solution. The possible benefits for vertical integration are many and varied. One of them is the reduction of some of the information asymmetries between the two actors: for example, the provision of adequate information on quantity and quality of future product supply. However, transactions between separate units carrying out vertically related activities can be difficult under some circumstances. These difficulties arise from information asymmetries. The improvements in information technology should help to diminish those problems. By the use of other tools, like genuine and innovative information systems, the new integrated unit can send adequate and just-in-time signals back to the seniors' ones units, increasing the positive contributions of vertical integration: Nowadays, there are demands for more specialized and customized clothes. In a vertical integrated chain of activities, the use of web technology structures, because of potential for information sharing along the marketing channel, are used to discover product characteristics and consumer demands, and to render product characteristics more in line with the consumers' demands.

## 6. References

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Figure 1. Theoretical model

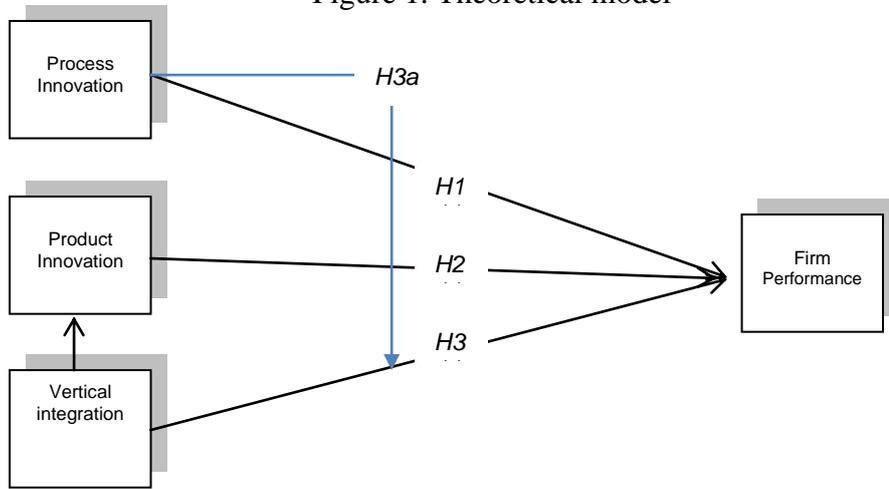


Figure 2. Graphical representation of an output-oriented DEA model.

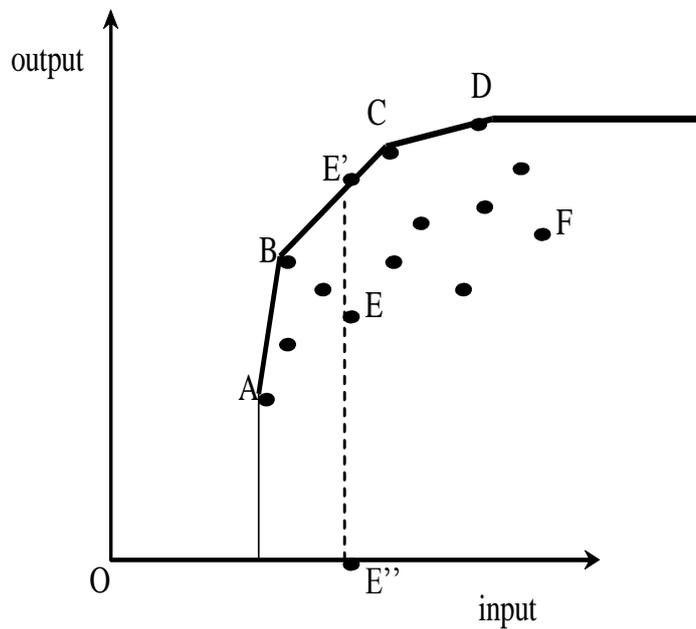


Figure 3. Level of process innovation vs. firm performance.

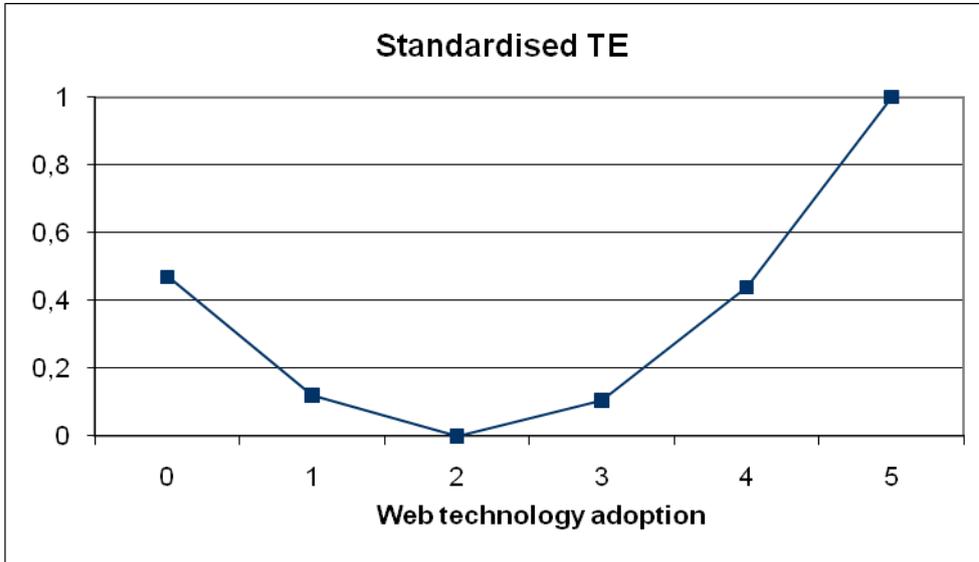


Figure 4. Interaction effects.

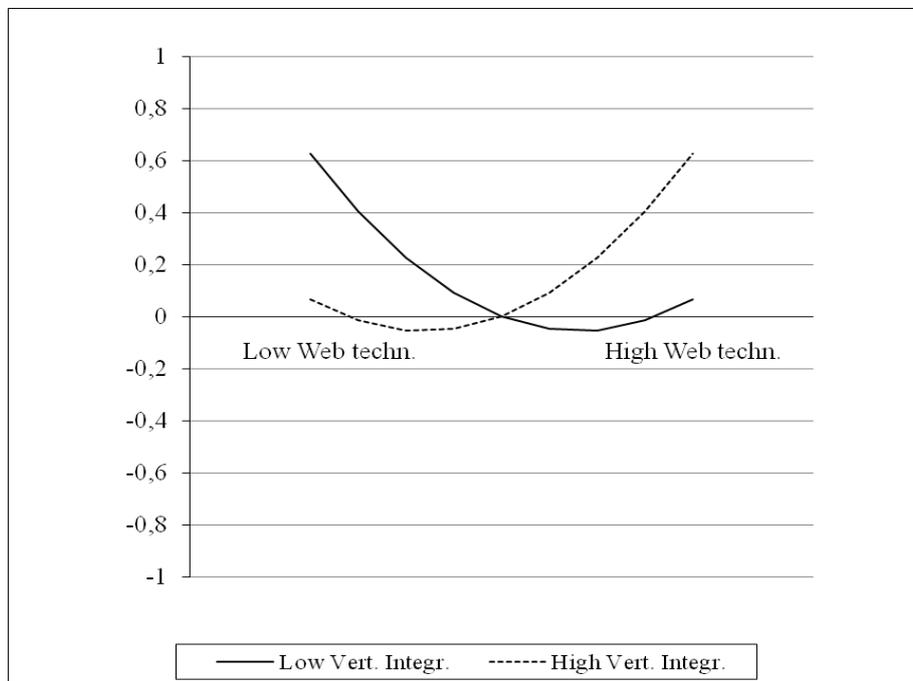


Table 1. Descriptive statistics.

	Mean	St. dev.	1	2	3	4
<i>1. Performance</i>	0.68	0.25	1			
<i>2. Web techn</i>	1.98	0.852	-0.028	1		
<i>3. Product innov.</i>	14.81	10.207	0.109	0.133	1	
<i>4. Vertical integrat.</i>	4.99	3.519	0.177	-0.048	0.519***	1

\*\*\* significant at the 1% level

Table 2. Regression results (dependent variable: efficiency).

	<i>Model 1</i>	<i>Model 2</i>
<i>Web techn</i>	-,154	-,149
<i>Vertical integrat.</i>	-,210	-,183
<i>Product innov.</i>	,267 *	,290 *
<i>Web techn</i> <sup>2</sup>	,183	,347 **
<i>Vertical integrat.</i> <sup>2</sup>	,101	,110
<i>Web techn * Vert. integrat.</i>		,279 *
<i>R-squared</i>	,119	,168
<i>R-squared change</i>	,119	,050
<i>F-change</i>	1,536	3,337
<i>Sign. F-change</i>	,193	,073

\* significant at the 10% level: \*\*significant at the 5% level