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FIRM DETERMINANTS IN NEW PRODUCT INTRODUCTION: A STUDY THROUGH SURVIVAL ANALYSIS*

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Abstract

The literature has broadly discussed the advantages obtained by pioneer firms under the concept of "first mover advantages". However, less attention has been paid to the study of the factors that determine entry timing. The present paper analyzes the firm's determinants in the introduction of a product innovation. The results obtained for the Cox regression in the case of the Italian ceramic tiles industry show that technological resources and firm size have a positive and significant influence on the likelihood of the innovation being introduced, while other factors, i.e. financial and marketing resources, have no influence on the adoption of the innovation.

Key words: survival analysis, determinants of entry timing, resources, *first mover advantages*.

1. INTRODUCTION

The literature has dealt widely with the study of the advantages in terms of productivity and results that pioneer firms can obtain through the incorporation of a new technology or introduction into a new market under the name of *first mover advantages* (Lieberman and Montgomery, 1988; Kalyanaram and Urban, 1992;

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Kerin *et al.*, 1992; Patterson, 1993; Nehrt, 1998). Nevertheless, not so much attention has been paid to the study of factors that may determine the time of entry into a new market. The strategy adopted to introduce a new product normally takes place under time pressure, as it is perceived that the detected opportunity will fade away unless the relevant steps are taken ahead of competitors. It is considered that profits will be gained by those firms that "move first" in this area of business, and the role of time is vital (Patterson, 1993). The entry time becomes, thus, a strategic factor of great importance.

The decision to enter in a new market is influenced by firm resources, apart from specific factors related to the situation such as degree of product innovation, available distribution channels, expected reactions of competitors, or luck. Mascarenhas (1992) points out that pioneer firms present differences in their characteristics and results in comparison with follower firms. In the same way, Robinson *et al.* (1992) report that pioneers in a specific product or market, early followers and late followers seem to present different profiles vis-à-vis their skills and resources, as per the comparative advantage hypothesis.

The aim of the present paper is to contrast the importance of a firm's factors in determining the moment a new technology required to produce a new product is incorporated. In order to carry out this objective, the rest of the paper is organized as follows. Section 2 provides a literature review. In Section 3 the various hypotheses to be tested in this paper are exposed. Section 4 provides a description of the methodology used, data, variables and statistical procedures. Section 5 presents the results, which are discussed in Section 6.

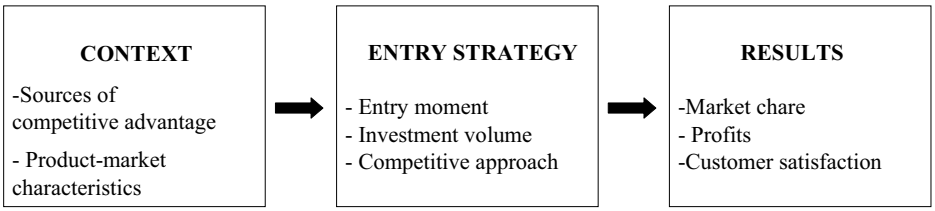
2. LITERATURE REVIEW

Entry in a new market or the incorporation of a new technology can be described as a process that starts from the context in which the firm is inserted in a specific moment (Green *et al.*, 1995). As Figure 1 shows, the entry strategy adopted depends on the context of the firm. This involves taking decisions about entry time, the magnitude of the investment and the competitive approach. The entry strategy has an influence on the results that the firm obtains, which will reflect the level of success of the product in its maturity. These results are assessed in the literature in terms of market share, profits, customer satisfaction, investment return, customer loyalty, etc.

Many studies have examined the results obtained by the firm in accordance with its context (Robinson and Fornell, 1985; Mitchell, 1992, Mitchell *et al.*, 1994; Nehrt, 1998), and the results depending on the entry strategy adopted (Moore *et al.*, 1991; Kalyanaram and Urban, 1992; Mascarenhas, 1992; Green *et al.*, 1995; Szymanski *et al.*, 1995; Robinson and Min, 2002). However, less

FIGURE 1

Market/product entry process (Green *et al.*, 1995)



attention has been given to the analysis of how the context influences a firm's entry time and entry order in a new market or to the incorporation of a new technology.

Green *et al.* (1995) identify two conditions that encourage firms to attempt an early entry. The first refers to the existence of first mover advantages, which must be more important than market and technology uncertainty. The second is that possibilities exist of capitalizing on the first mover advantages, i.e., that the firm has sufficient resources at its disposal.

First mover advantages are defined as the benefits that a firm reaps from being the first to adopt the decision to enter in a specific market or to commercialize a new product. The earlier the market entry, the better the long term results will be, and the more important the first mover advantages are, the more interested the firm will be in adopting the new technology. Nevertheless, if the "best" firms decide to enter first, the order of entry may not be as important *per se* to the results, as the first mover advantages are a consequence of the greater strength of the firm in comparison with followers. In this case, the time of entry should be considered as an endogenous variable, given as a result of the firm's resources and attributes (Kalyanaram and Urban, 1992). This evidences the importance of firm factors in determining entry timing.

The moment the technology is adopted can be modelized as a growing function of the expected first-mover advantages and presents a positive relationship with the firm's resources. The more strategic the resources required to adopt a new technology are and the more difficult they are to imitate, the longer the delay in the entry of new competitors will be (Robinson and Min, 2002). According to Bukszar (1997), firms are conditioned in terms of the innovation challenges to which they can respond by their management skills, distribution channels, productive skills and R&D resources. These factors reduce the speed of organizational change to a slower pace than the change in the technological knowledge basis and the market conditions. Thus, the decision on whether to enter a new market must be reached by balancing the risks of an early entry and the loss of opportunities involved in entering too late (Lilien and Yoon, 1990).

Empirical studies on the determinants of the introduction of an innovation consider entry timing as a dependent variable , thus distinguishing between pioneers, early followers and late followers (Robinson *et al.*, 1992; Szymanski *et al.*, 1995). The optimal entry moment depends on firm and industry factors. With regard to firm characteristics, the literature has mainly focused on the study of the differences in resources and functional capabilities, and in organizational attributes. Following Mascarenhas (1992) and Robinson *et al.* (1992), pioneers have different resources and capabilities at their disposal compared with followers. Thus, the financial, marketing and technological resources of the firm, together with its organizational attributes, can determine the decision to enter in the market or to adopt a new technology, and the moment in which that entry takes place (Robinson *et al.*, 1992; Schoenecker and Cooper, 1998).

Concerning functional resources, first, strong financial resources increase the likelihood that a firm will be a pioneer (Robinson *et al.*, 1992). These resources allow for a greater entry investment and a better positioning, as they usually guarantee self-financing to cover the costs of product and market development (Green *et al.*, 1995). Second, Robinson *et al.* (1992) consider that the initial marketing and commercial resources and capabilities differ, but they are no stronger in the pioneer firms than in the later entrants. Lieberman and Montgomery (1988) find that strong marketing resources do not encourage market pioneering, and Lilien and Yoon (1990) confirm that, in the maturity stage, significantly greater market expertise increases the likelihood of a later entry in the market. According to these authors, strong marketing resources increase the likelihood of a later entry in the market. Third, in Lieberman and Montgomery's (1988) work, firms with an excellent R&D performance in their new product tend to find first mover advantage more attractive. However, Robinson *et al.* (1992) report that R&D resources do not have a significant influence on entry order, and do not imply either higher survival rates or a greater short- and long-term market share (Mitchell, 1992). This somewhat unexpected result may be due to measurement errors (Robinson *et al.*, 1992), or to the fact that firms have acquired these resources as a reaction to the innovation in other firms, or that they have made a mistake when acquiring these resources (Mitchell, 1992).

Regarding the organizational attributes, previous literature has analyzed the influence of firm size (Robinson *et al.*, 1992); past experience in organizational change and the presence of inertia in the firm (Mitchell, 1992; Baptista, 2000); the firm's commitment to the markets affected by the new technology (Robinson and Fornell, 1985; Moore *et al.*, 1991; Mitchell, 1992); the proximity of the main market compared with the target market (Fuentelsaz *et al.*, 2002); and the degree of specialization of the firm (Szymanski *et al.*, 1995; King and Tucci, 2000). In this paper we focus on the two first above-mentioned variables, as they have been considered to be the most relevant in previous studies (Mitchell, 1992; Robinson *et al.*, 1992; Schoenecker and Cooper, 1998; Baptista, 2000).

First, following Robinson *et al.* (1992), the firm's size has a positive impact on entry timing, as the bigger the firm, the more likely it is to be able to obtain the necessary internal and external funds, the bigger its capacity for covering transitory losses, and the better its reputation will be. Second, according to Population Ecology (Hannan and Freeman, 1977) and the Institutional Theory (DiMaggio and Powell, 1983), the adoption of a new technology is a consequence of factors related to the inertia and the institutionalization of change. Mitchell (1992) considers that the older the firm is, the less it innovates. Inertia depends, thus, on the firm's size, as well as other factors as the date of incorporation, the previous returns and the ownership of the capital (Mitchell, 1992; Baptista, 2000).

In summary, following Wong (1992) the satisfactory introduction of a new product or technology depends on the firm's capacity to coordinate its functional (financial, marketing, technological) and organizational resources in accordance with its entry strategy.

3. HYPOTHESES

In order to ascertain the importance played by firm factors in determining the moment of incorporation of the new technology necessary to produce a new product, we consider the following hypothesis:

In line with previous empirical evidence (Mascarenhas, 1992; Robinson *et al.*, 1992), we may expect to see a significant difference in resources between firms that incorporate the technology necessary to produce a new product and those that do not.

> *H1: The financial, marketing and technological resources prior to the incorporation of a new technology differ between firms that innovate and those that do not.*

Differences between firms that adopt the new technology and those that do not lie in their functional resources and also in their organizational attributes. With regard to differences in functional resources, it is expected that greater financial resources will increase the likelihood of the firm entering the market (Robinson *et al.*, 1992; Green *et al.*, 1995). As for marketing resources, Robinson *et al.* (1992) point out that they encourage later entry, when analyzing the decision on whether or not to incorporate a new technology. Finally, even if, according to Robinson *et al.* (1992), the technological resources do not seem to have a significant influence on the entry decision of the firm, the same authors point out that such a result is not logical, and it is expected that the greater the technological resources of the firm are, the sooner the decision to incorporate the new technology will be taken.

H2a: The decision to incorporate the new technology and the moment in which this decision takes place depend positively on the financial and technological resources that the firm has available, and negatively on its marketing resources.

In reference to the organizational attributes, as Robinson *et al.* (1992) state, firm size is expected to have a positive impact on the speed of entry, because of its positive relationship with its ability to obtain the necessary financial resources to undertake the investment.

H2b: The decision to incorporate the new technology and the moment in which this decision is taken depends positively upon the size of the firm.

Finally, due to the presence of inertia, it is expected that the older the firm is, the less likely it will be to innovate (Mitchell, 1992; Baptista, 2000). However, older firms are more likely to be bigger, and in this sense, they may be more likely to incorporate the new technology as a consequence of the relationship between size and financial resources referred to above. But as the latter is an indirect effect, we consider the former possibility when stating our hypothesis, i.e., the longer the firm has been established, the less likely it will be to incorporate the new technology.

H2c: The decision to incorporate the new technology and the moment in which this decision is taken depend negatively upon the age of the firm.

4. METHODOLOGY

In order to test the above-mentioned hypotheses, we analyzed the determinants of entry timing for the incorporation of the necessary technology to produce a new product, in this case porcelain stoneware tiles, by Italian ceramic tile producers. In this section the characteristics of the data and their origin are presented, and the variables and statistical procedure are described.

Data

The present study was carried out on a sample of 180 Italian ceramic tile producers. The study covers the period from 1982 to 2001 (inclusive). We focused on the Italian ceramic tile industry because it is the world leader in the production

of ceramic tiles and the pioneer in the production of porcelain stoneware. The introduction of porcelain stoneware tiles was chosen because it requires a major investment in technology that is not available to all firms, together with advanced technical expertise and specialized personnel. Furthermore, this kind of product presents differentiated features in comparison with more traditional products and it is sold at a higher price, thereby involving a different customer perception.

In order to eliminate possible factors that could distort the results, we screened the data base in two ways. First, producers of glazed porcelain ceramic tiles were excluded from the sample, as they do not require an additional investment in technology. Second, commercial firms and non-producers of porcelain stoneware tiles were eliminated from the sample.

Variables

Two types of database were considered: financial data (balance sheets and book income/loss) and general data on the firms' age, size and products. Information was obtained from the annual reports "Andar per Ceramiche" for the period 1986-2001.

In order to test the aforementioned hypotheses, the following variables were obtained. To measure the financial resources, the ratio Own resources/Total assets was calculated (Robinson *et al.* 1992). The commercial or marketing resources were measured by considering the commercial margin (Robinson *et al.* 1992), defined as the ratio between the value of production after deducting the production cost, and the value of production. The technological resources were calculated as the ratio between the net accounting value of machinery (machinery less accumulated depreciation) and total assets. This proxy is used, as no data on R&D expenditure is available for most firms and periods (Robinson *et al.* 1992).

The size of the firm was measured as the volume of assets and it is included in the model as a time dependent variable. In addition, the age of the firm was calculated from the year of its foundation. This variable was considered as a proxy of the existence of organizational inertia. All variables, with the exception of the volume of assets and the age of the firm, were expressed as ratios in order to avoid the effect of time on the absolute values, as this could make comparisons between periods difficult.

Statistical procedure

We use survival analysis to study the determinants of entry timing. This statistical method has certain advantages over alternative procedures used in the previous literature, such as linear regression (Robinson and Fornell 1985; Mitchell 1992), exponential regression (Kalyanaram and Urban 1992; Patterson 1993),

logit model (Robinson *et al.* 1992; Robinson and Min 2002) or meta-analysis (Szymanski *et al.* 1995). Lieberman and Montgomery (1998) consider that Survival Analysis is a better methodology for two reasons. First, survival models allow us to deal with censored data, i.e. cases in which the event has not yet taken place. Second, survival analysis with longitudinal data enables all the available information to be used to study, on one hand, the determinants of the event to take place, and on the other, the determinants of the event moment.

In the present paper, survival analysis allows us to use information on firms that have not yet incorporated the technology necessary to produce the new product, and furthermore, with only one estimation of the model, it allows us to contrast the significance of the different firm factors in determining both the decision on whether or not to incorporate the innovation, and the moment of the decision.

Survival analysis includes several statistical techniques suitable for studies in which certain cases (firms) are studied over a period of time. These procedures measure the time interval between an initial event, in this case the onset of porcelain stoneware production, and the final event or the end of the studied period (incomplete or censored time), if the event does not take place. It aims to determine the likelihood of the event happening and the evolution of the occurrence rate of this event (risk rate) during the period of study. In these models, the dependent variable is the time elapsed between the initial moment and the event, with the event being defined as the set of qualitative changes that take place after a specific moment in time, i.e. the incorporation of a new technology.

The Cox Proportional Hazards Model (1972), which assesses the effect of a set of determinant factors, is included amongst these techniques. This method integrates traditional regressions and survival analysis. It enables us to include in one single equation the estimation of the determinants of both the entry decision and the moment this decision is taken, while at the same time taking into account the resources of the firm and controlling for interactions. Thus, it provides a general, flexible and efficient way of analyzing this kind of situation, as it is the result of the generalization of the comparison between survival curves.

The hazard function h(t; X) measures the likelihood of an event happening – the start of porcelain stoneware production, in a specific moment of time *t*, conditioned per unit of time, if it had "survived" until the previous moment. In the present paper, this is the likelihood of incorporating the technology to produce porcelain stoneware tiles in moment *t* for the firms that present a specific set of values in the relevant variables. The hazard rate is presented in expression (1):

$$h(t;X) = h_o(t)\, e^{\beta' X} = h_o(t)\, e^{(\beta 1 X1 + \beta 2 X2 + \ldots + \beta p Xp)} \quad (1)$$

where $h_o(t)$ is the baseline hazard rate function, which only depends on time and represents the hazard rate of the hypothetical case of a firm presenting value 0 for

all the predictive variables; e^{β} represents the factor for which the hazard rate is multiplied when *X* increases in one unit; and β_1, β_2, ... β_p are the parameters to be estimated, whose signs show the increase or the reduction of the hazard rate when their corresponding co-regressor vary. The likelihood density function represents the proportion of cases of the total sample that "die" in a specific interval, i.e. the likelihood of dying in a specific moment. It is a semi-parametric model, as the function $h_0(t)$ is not specified *a priori*, but inferred from the data during the estimation of the p beta parameters.

In the present paper, we define the incorporation of the technology necessary to produce porcelain stoneware as the event. In order to test our first hypothesis we consider the contrasts of the means difference and the variance ratio. We test the three parts of the second hypothesis jointly through the estimation of the parameters of the Cox regression.

5. RESULTS

In order to test Hypothesis 1 we compare the mean values of financial, marketing and technological resources for firms that decide to produce porcelain stoneware and for the control sample in the three years previous to the introduction of the new product. We use the mean difference *t* statistic. We also test for the existence of significant differences between the variances in both samples with the Levene test.

TABLE 1

Statistics to contrast differences in means and variances between the resources of the innovative firms and the resources of the control firms

RESOURCES	DIFFERENCE OF MEAN VALUES	t	LEVENE TEST
FINANCIAL	0.0114	0.73	6.04 (b)
MARKETING	0.0237	1.81(a)	17.23 (c)
TECHNOLOGICAL	0.0494	1.20	5.60 (b)

(a) Significant at 10%; (b) Significant at 5%; (c) Significant at 1%

Table 1 shows that only the marketing resources mean is significantly higher for the sample of innovative firms. Nevertheless, the variance of the financial, marketing and technological resources is significantly higher for the control sample. These results indicate that Hypothesis 1 is not supported, as only marketing resources are different between samples.

In order to test the second hypothesis a Cox regression is estimated. The model includes a quantitative variable (time), a categorical variable (producer/

non producer of porcelain stoneware) and five co-regressors (financial resources, marketing resources, technological resources, firm size, and the year the firm was founded). The size of the firm is considered as a time dependent variable, as it is assumed that the volume of assets tends to increase year after year. Due to limited availability of information, the analysis could not include the firms that were already producing porcelain stoneware in 1983, as the first available accounting data refer to 1986. Thus, the present paper focuses on the firms that started producing porcelain stoneware tiles after 1990, which reduces our final sample of innovative firms to a total of 88.

Table 2 presents the values of the estimated coefficients, the value of their corresponding t statistics and e^B. The value of e^B represents the factor that multiplies the hazard rate when the corresponding variable is increased by one unit.

TABLE 2

Estimated coefficients for the Cox regression

VARIABLE	B COEFFICIENT	T	EXP(B)
Financial resources	1.0078	1.09	2.7397
Marketing resources	1.3862	0.17	3.9995
Technological resources	2.3865	6.31(c)	10.8750
Size	0.0000023	3.49(c)	1.0000
Date of incorporation	-0.0114	0.63	0.9887

(a) Significant at 10%; (b) Significant at 5%; (c) Significant at 1%

Alternatively, the regression was estimated excluding the variable referring to the year of foundation in order to avoid multicolinearity generated by the possible relationship between it and the size of the firm (Baptista, 2000). The results obtained were very similar to the previous ones. The same procedure was followed excluding the size variable and the results again were very similar to those obtained in the previous estimations[1].

As we can infer from these results, the technological resources and the size of the firm have a significant effect on the likelihood of the innovation being introduced in a specific moment of time. Thus, big firms innovate more than small firms, coinciding with the results of Pennings and Harianto (1992). From the value of the exponential for coefficient B, the importance of the technological resources on the likelihood of the new technology being introduced can be inferred. The factor that multiplies the hazard rate when the technological resources increase by one unit is almost 11 times this increment.

The signs obtained for the estimated coefficients are not all consistent with the hypotheses posed. Thus, with the exception of the year of foundation, all the

[1] The results are available for all interested parties.

coefficients are positive, i.e. the bigger the size of the firm and its technological, financial and marketing resources, the more likely it will be to incorporate the technology necessary to produce porcelain stoneware. The negative value of the coefficient related to the year of foundation of the firm in the Cox model means that the later the foundation, the less likely innovation is to take place. Contrary to our intuition about the presence of inertia or obstacles for organizational change, older firms are the first to introduce the new product. This could be due to the fact that older firms are larger and have more resources, which are the most relevant factors in determining the introduction of innovation in these firms. In reference to the marketing resources, results show that they exert a positive influence on the time of entry, a result that does not support Hypothesis 2a.

Although the signs of the parameters are in accordance with the proposed hypotheses, only two of these parameters –those related to firm size and technological resources- are significant. Thus, it cannot be confirmed that financial resources, marketing resources and the firm's foundation year are determinants of the moment in which the technology necessary to produce porcelain stoneware is incorporated.

6. DISCUSSION

The present paper examines the importance of different firm factors in determining the moment a new technology necessary to produce a new product is incorporated. Instead of the traditional regression techniques used in the literature –i.e., linear, exponential and log regressions-, survival analysis techniques were applied. These techniques are more suitable, as they allow us to consider censored data, i.e. firms that have not yet adopted the new technology, and test the importance of the factors considered to determine, on one hand, the decision of whether or not to incorporate the new technology, and on the other, the moment in which it is decided to adopt such an innovation.

The results show that, before deciding on the introduction of the porcelain stoneware, there are only statistically significant differences in the marketing resources of the firms that adopt the new technology compared with those of the firms that do not innovate. In contrast, there is no evidence of significant differences regarding financial and technological resources between the two firm samples. These results may suggest that there are no differences in terms of resources between the firms that adopt the new product and those that do not; nevertheless, there are significant differences in variance between the two firm samples. The dispersion of the values of the financial, marketing and technological resources is much higher for firms in the control sample than for those that adopt the new technology. These differences may hide the effect of the firm's resources as determinants of the adoption of the new product.

In order to overcome these limitations, we tested whether the likelihood of the firm innovating in a specific moment depends on the financial, marketing and technological resources, the size and the age of the firm. A Cox regression model was estimated. From the estimated coefficients it can be inferred that, even if all coefficients are positive, only those related to the firm's size and technological resources are statistically significant. Consequently, these results show that only the technological resources and the size of the firm increase the likelihood of the new product being incorporated. In contrast, financial and marketing resources do not have any influence on the moment the new technology is adopted, in spite of the evidence shown in the previous literature.

These results suggest two additional considerations. First, regarding the suitability of using survival analysis techniques, the Cox regression allows us to estimate the significant effect of technological resources on the moment the new product is adopted, even if there are no significant differences in the volume of resources before the innovation between the firms that adopt the new product and control firms.

The second consideration refers to the results of the present paper. Only technological factors, together with the size of the firm, determine the moment the new product is adopted. Other factors considered by the previous literature as determinants do not seem to have any influence on the decision of whether or not to adopt the new technology. The limited availability of historical information for the Italian pioneer firms, and the lack of data on certain relevant variables for all the years in the period under study have compelled us to define marketing and technological resources differently from the definitions established in the literature. This fact could explain the differences between our results and those obtained in previous research. The conclusions obtained highlight the need for further investigations that help to determine the role of the firm's various resources in the decision to adopt a new product.

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