UNIVERSIDAD CARLOS III DE MADRID
working papers

Working Paper 03-01
Business Economics Series 01
January 2003

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PERSISTENCE AND ABILITY IN THE INNOVATION DECISIONS

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Abstract

The main concern of this paper is to analyse the complementarities between the decisions to carry out both product and process innovations. We also try to identify the main determinants of the innovation activity as well as to separate the experience effect of the firm (capacities, routines as organization) from the experience effect of the manager (skills, abilities). It has been common when facing the study of technological change, to consider innovation as a homogeneous activity. The main analyses have focused on the determinants of such activity trying to explain decisions, counts or R&D expenses in the context of a unique activity. Several recent works, however, are worried about the possibility of analysing innovation distinguishing among different types according to the final purpose of this activity. We focus on two different decisions, product and process innovations, using typical discrete choice specifications (univariate and bivariate models) and also binary choice models with heterogeneity. Among the results, we find complementary but asymmetric effects concerning both decisions in static models even controlling heterogeneity. We also test whether the persistence in conducting innovation activities matter. We do so in an extensive database that provides information about manufacturing firms. Our results point towards the importance of both ability of the manager (unobserved heterogeneity) and experience of the firm (dynamics in the equation indicator).

Key words: product innovation, process innovation, panel data, discrete choice.

JEL Class. : C72, O31

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1. Introduction

The topic of innovation has garnered the interest since the seminal work by Schumpeter (1942), probably because it constitutes the main source of economic growth. However, until the advent of panel data sets, there was little empirical evidence to link the innovative stance and the performance of the firms. Recent work that uses panel databases on firms has demonstrated the importance of innovation to growth in firms, then translated to economic growth.[1] Our main interest in this study is not connected with the link between innovation and growth but we are interested in analysing the factors that condition whether a firm adopts an innovation policy. Not all firms successfully innovate despite the benefits of doing so. The advent of innovation surveys that collect data on a variety of firm characteristics provides us with the opportunity to study the differences between firms that innovate and those that do not innovate.[2]

More specifically, our first and main concern is the investigation of the complementarities between the decisions to carry out both product and process innovations. According to this, we consider that the traditional measures of R&D activities (expenditures, patents, employment in R&D) do not properly capture real decisions. So, we will use information of both product and process innovations following a new strand of research (Arrow, 1962; Yi, 2001). From a strategic point of view, managers decide about the implementation of a better innovation policy in order to obtain a better position of a company. They decide to introduce a new product or a new production process, to enter a new market or to change the organization structure of a firm. It implies that such decisions form part of the firm innovation activity and the reasons to carry out one or another are different, so it is then possible that innovation should not be treated as a homogeneous activity.

This study uses the resource-based view (RBV) to study the complemantarity among the innovation decisions. Many analysis have concentrated in the complementarities among business strategies (Veugelers and Cassiman, 1999); however little has been done about complementarities among innovation decisions. The RBV also serves us to test whether the heterogeneity of the firm is due also to the different forms to monitor the firm. This objective is difficult to pursue since data available does not directly provide with such information, although it is still possible to use some statistical instruments to control and estimate the effects of manager's

[1] See for instance Baldwin (1998).
[2] Seen for instance Sterlacchini (1994) for Italy and Brouwer and Kleinknecht (1996) for Holland.

decisions on the innovation decisions inside firms. In addition to identify the main determinants of innovation, we test whether product and process decisions are independent of each other or are complementary activities within the firms.

A second point is to separate the experience effect of the firm (capacities, routines as organization) from the experience effect of the manager (skills, abilities); because we argue that managers have more incentives to develop innovation activities that translate into visible results –product innovations- than to focus on efficiency policies –process innovations-. This objective is not easy because we do not have observable information about the experience of the manager in taking decisions of innovation activity. So, we assume that the manager's experience is a fixed effect and it could be correlated with the decision to carry out one or another innovation activity. On the other hand, the experience of the firm will be approximated both by industry effects and past innovations. Whether or not there exists association between both variables would be also a purpose of this paper although we are aware of the difficulty in isolating those effects.

However, the paper has some interested and related goals. The third aim involves the usually known as the Schumpeterian hypotheses about the extent to which size of a firm and competition in the industry environment stimulate innovation. It is sometimes claimed that innovation is fostered by a climate where firms are large or in industries where there is less competition. While Arrow (1962) made a claim contrary to Schumpeter (1942), there is mixed evidence that either matter (Scherer, 1992). Because of its importance, this issue continues to receive attention (Cohen and Klepper, 1996a, 1996b using US data or Martínez-Ros and Labeaga, 2001 using Spanish data). We are also worried about the effect of the owning of firms in the innovation regime of Spain. Several authors have stressed the special role of the multinational firm in transferring special innovation skills from one nation state to another.

In order to test those hypotheses we use data at firm level corresponding to approximately *1000* Spanish manufacturing firms along the period 1990-1999. The database is provided by the Spanish Industry and Energy Ministry and involves approximately *2500* firms belonging to the manufacturing sector each period. The sample we use consists in an unbalanced panel that allows us to keep representativeness of the sample as well as to fully exploit the dynamic nature of the model. Before estimating the model, we conduct an extensive descriptive analysis in which we try to emphasize whether past can explain current decisions, computing frequencies conditional on past frequencies but unconditional on other regressors.

There are several alternatives to estimate the model. Previous empirical evidence on this issue is mainly based on the estimation of univariate probit, count data or two-part models (see Martínez-Ros, 2000 and Martínez-Ros and Labeaga, 2002). We try in this paper all kind of discrete choice models in an attempt to individually and jointly test all the proposed hypotheses. Since a fundamental issue to explain unobserved differences in firms' behaviour is the control of unobserved heterogeneity (Blundell, Griffith and Van Reenen, 1995), we specially focus in controlling unobserved individual heterogeneity. In this sense, we take account of firm effects (manager's experience or ability) possibly correlated with some conditioning variables (past innovation firm's experience) using recent estimation proposals (see, for instance, Arellano and Carrasco, 1996 and Bover and Arellano, 1997).

Among the main findings we find complementary but asymmetric effects concerning both decisions in static models even controlling correlated heterogeneity. However, once we include experience in the own innovation decision, the significance of the other innovation indicator vanishes. The cross effects amongst the two decisions can be considered both correlated heterogeneity or spurious dependence in static specifications, but they can be due to spurious dependence once correlated heterogeneity has been controlled for. This results points towards doing innovation in the past as the main determinants of conducting contemporary innovation activities (i.e., firm effects). Other interesting result refers to the degree of vertical integration of a firm. When, we control by the experience and heterogeneity, we obtain significance and the expected effects of this variable on innovations decisions. We confirm our main hypotheses: large firms with higher technological opportunities in the market that dedicate big investments in physical capital find more profitable to carry out innovations in new processes than in new products. That is, the internal resources of a company follows being important even controlling by ability and persistance in innovating.

The rest of the paper contains four sections. In section 2 we motivate the paper and justify the specification used in the empirical analysis. Section 3 a description of the model is made. Section 4 is devoted to the empirical analysis and discussion of results. We summarise the main findings and provide some conclusions in section 5.

2. Innovation as a heterogeneous activity

The definition of innovation is wide because it includes the introduction of a new product or service, improvements or changes in the production process, materials and intermediate inputs and management methods. An issue arises with the possibility of some kind of these innovations are in some way related, in particular, the introduction of new products and the use of new designs and procedures to manufacture products. We are interested in addressing whether companies have some degree of discretion in the decision to carry out innovation in products or/and innovation in process. As Milgrom and Roberts (1990) pointed out, product and process are complements because they mutually reinforce through increases of the level of any of them leads to increases of the marginal profitability of the other.

In the literature, there no exists much evidence that investigates the relations among product and process innovations. A few attempts have been made Lunn, (1986), and Kraft (1990) have considered the possibility that innovation activity could be divided into different types attending to its final purpose. Recent papers (Fritsch and Meschede, 2001; Flaig and Stadler, 1998) found that both activities are related, implementation of a product innovation can make corresponding process innovation necessary, while process innovation may enable a firm to considerably improve the quality of its products or to produce completely new products. Bonano and Haworth (1998) included vertically differentiated product innovations and Rosenkranz (1995) assumed horizontally differentiated product innovations. Both articles try to fill the existing gap in the literature about what factors might be important in a firm's decision whether to direct R&D expenditure towards product innovation or towards process innovations, focusing in the degree of competition market in which firms find themselves.

The present paper extents the idea that the decisions and conditionings of firms carrying out some innovation types are not the same, and try to corroborate whether both types of innovations are complements or in contrast firms develop one type of innovation as an inertia. We focus on the decisions to introduce a new product (product innovation) or to introduce new production processes to achieve efficiency (process innovation). Product innovation relates to the generation, introduction and diffusion of a new product (production process *ceteris paribus*) while process innovation relates to the generation, introduction and diffusion of a new production process (product *ceteris paribus*). An innovation in product leads to a perception as a new product by the consumer if any attribute of this product has changes (service, design, packaging, quality). In that case, we are assuming that firm is conducting a strategy of product differentiation.

When a firm change or improve the process of transforming inputs in outputs, it is developing an efficiency strategy since the impact consist of reducing the cost of production either being more flexible or increasing the intensity of capital. Both decisions can be independent but we may be aware that both innovations may happen together. Companies may acquire new technology by purchasing that technology embodied in new capital equipment. Thus the capital that embodies the technology is a product innovation but the buyer is acquiring a process innovation. We check the factors determining both types of innovations as well as their interrelation. Our study tries to deep into this relationship and in the investigation of the role of manager expertise in the decision innovations.

3. THEORETICAL MODEL AND HYPOTHESES

The basic problem of a firm is to maximise its value. The objective is to consider the introduction of some research activity as a gain for a better knowledge stock and improvements on the probability of developing future innovation (Reinganum, 1989; Blundell, Griffith and Van Reenen, 1995). The relationship between innovation strategy and innovation decision constitutes a production function of innovations where the success in some innovation decision depends on the effort made by the firm in the past since any innovation strategy has a long term horizon to achieve returns (Piergionanni et al., 1997, use also this approach). So, the innovation decision will result as a consequence of transforming the knowledge accumulated by the firm in the past, the technological opportunities offered by the market, internal resources other market characteristics, and the experience of the manager. All the hypotheses expressed in the paper are formulated distinguishing the effect of some factor in each innovation type, so we expect to find different effects according to innovation activity and conditioned to the manager expertise.

The knowledge stock

We expect that the technological capital will have a positive impact on the innovation activity, since the search effort, which determines the technological capital, is intended precisely to be able to improve products and processes. The technological knowledge stock captures previous R&D effort done by the firm affected by a depreciation rate. We follow Griliches and Mairesse (1984) or Hall (1990) in the sense that search contributes towards the innovation stock by generating a constant stream of incremental innovations.

> *H1: The accumulated knowledge stock encourages firms to develop some innovation activity.*

Technological opportunities of the market

The idea that not only the monopoly power affect the technological activities of firms but the existence of other important environment factors has been summarized in Cohen and Levin (1989). Industries with more technological opportunities are expected to encourage innovation activity since the accumulated knowledge of the market, mostly shared by many of the firms due to spillovers or other effects, reduces the cost of translating knowledge into new products and processes. But at the same time, it may work against innovation if the innovating firms consider the innovation susceptible to be imitated by a rival in a short period of time. It is specially observed in the innovation in products (Lunn, 1986). Notice that it captures an externality of R&D capital as Crepon and Duguet (1997) pointed out. Piergiovanni, et al. (1997) found out that spillovers from university research are a relatively more important source of innovation in small firms, while spillovers from industrial research are more important in producing innovation in large ones. From all we conclude that the net effect of this determinant is uncertain.

> *H2: Higher technological opportunities in the market act as barrier to imitation leading to increases in the innovation in products.*

Internal Resources

In the Schumpeterian tradition, the <u>size</u> of the firm has been used as main element to test the internal resources. Previous empirical research has tested the effect of size on innovation activity (Acs and Audretsch, 1987; Kleinknecht, 1989; Piergiovanni et al. 1997; Martínez-Ros and Labeaga, 2002) with mixed results but, in many of the cases, innovation activity was measured in terms of inputs rather than outputs.[3] The apparent disarray in obtaining consensus of the effect of firm size on innovation activity responds, in many cases, to the omission of many controls of firm and market characteristics despite the demonstrated importance of such effects

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[3]Pavitt *et al*. (1987) found that innovation intensity was greater for large firms and small firms, and smaller for medium-sized, in the UK industry. In contrast, Soete (1979) suggested that R&D intensity increased with size in a number of sectors in the US. Blundell *et al.* (1993) using the innovation counts found that higher market share firms innovate more, while firms in competitive industries tend to have a greater probability to innovate.

(Scott, 1984). The size distribution of firms varies across industries, in part because of differences in the degree of scale economies in production and distribution. Thus, there is a good reason to believe that fixed industry effects are correlated with firm size and that the omission of such effects will bias estimates of the effects of size on innovation.

Similarly, firm characteristics such as diversification, financial capability, and returns of R&D in larger markets or the existence of more experience in innovation in the structure of the organization confirm the positive correlation with large firms (Cooper, 1994; Hitt et al. 1990; Graves and Langowitz; 1993; Galende and Suárez, 1999). So, in order to isolate the size effect on innovation for a given knowledge stock is important to control for market competitive conditions and other firm features. For a given stock of technological capital and opportunities, the size of the firm may influence the output of innovations due, for example, to differences in other physical, human and financial resources across firms with different size. In general, a positive effect of size on innovation output is expected, since larger firms tend to be less financially constrained. However, it may also happen that larger firms view themselves as less threatened by competition and lower the rate of innovation in order to not to erode profits of current products and processes. Besides, if the firm has monopoly profits the incremental profits of innovation will tend to be relatively lower than in a firm facing more competition. Moreover, large firms may also be subject to more bureaucratic controls and dysfunctions, which may affect negatively their capacity to translate capital stock into innovations (Cooper, 1994; Hitt et al. 1990; Collier, 1983; Williamson, 1985).

Cohen and Klepper (1996a, b) developed a model where the main hypothesis were that the return of an innovation is positively related with the size of business unit and that this relationship is stronger for process innovation than for product innovation. Fritsch and Meschede (2001) test the same hypothesis using the different kind of R&D expenditure but the findings are not very pronounced. We expose our hypotheses in the same line.

H3: Large firms find more profitable to invest in process innovation than in the search of new product innovations.

The characteristics of the production technology may also affect the decision to introduce innovations for a given stock of technological capital; one variable used to differentiate production technologies is the intensity of physical capital (*KSA*). Firms with more capital-intensive technologies will tend to innovate more if, as expected, the rents of innovation are less threatened as, to exploit the innovation, high investment in physical capital is required. It may also happen that more capital-intensive processes provide less room for innovation since they are more automated and rigid. The final effect of capital intensity on innovation activity is uncertain. Kraft (1990) included only the capital intensity in the product equation obtaining a positive effect, but it is more an empirical issue.

H4: The physical capital is more important in the development of new process innovations rather than in the production of new products.

Industrial Organization factors

A common market element used in the literature is the market structure. We will refer first to the degree of competition in the product market proxied by market concentration, which is the typical variable used (see Cohen and Levin, 1989 for a complete overview about the relationship between R&D and concentration and an extensive discussion about the ambiguous predictions obtained in empirical studies). In general, the empirical evidence supports Schumpeter's arguments that firms in concentrated markets can more easily appropriate the returns from inventive activity. Others works find evidence that market concentration do not promote R&D because the expected incremental innovating rents are larger in competitive markets than under monopoly conditions (Arrow, 1962; Bozeman and Link, 1983; Delbono and Denicolo, 1998; Yi, 1999). A discussion about the right sign of this variable needs to be related to the endogeneity of the measure used in the empirical analysis, i.e. the concentration ratio. A positive sign would give support to Schumpeter's hypothesis while a negative sign would be in accordance with Arrow's predictions. The introduction of this variable in both innovation equations also allows us to test for different effects of market competition in product and process innovation (Lunn, 1986 and Kraft, 1990).[4]

The discussion above suggests that there are many theoretical issues, which will have to be tested empirically in order to determine the sign of the net effect of the explanatory variable. The lack of a clear theory also reinforces the importance of using econometric estimation procedures that minimise estimation biases. As Levin and Reiss (1984) and Levin, Cohen and Mowery (1985) showed, the endogeneity of

[4]These authors separate process from product innovation and find opposite results. While in Lunn (1986), concentration is precisely estimated only in the process equation, Kraft (1990) finds that

concentration produces biases in the estimates of the effect over innovation activity. Acs and Audretsch (1987) found that large firms are more innovative in concentrated industries with high barriers to entry, while smaller firms are more innovative in less concentrated industries that are less mature. Blundell, Griffith and Van Reenen (1995) obtained innovation activity increases with market share and decrease with market concentration. Therefore, in the long run increase in market share may have a net negative effect on innovation if it also increases market concentration.

H5: We expect that the market competition will affect the decisions to innovate but the sign of the effect is ambiguous.

Manager's ability and firm's experience

The RBV offers a good framework to develop the idea that companies are heterogeneous in terms of the resources they control. Organizational resources consist of all assets, capabilities, attributes and knowledge a firm possesses that enable it to develop and implement strategies that improve its performance (Barney, 1991). A firm's resources can be a source of competitive advantage in markets when it is difficult for the rivals to obtain like resources. Scarce resources create entry barriers for firms that do not have them (Wernefelt, 1984). There are two very important resources the firm expertise and the ability of the manager in deciding which type of innovation is good for the company. Firms with a high experience in innovating, develop routines, synergies and capabilities inside the firm among departments and employees that the probability to obtain success in this activity fosters them to follow innovating.

However, managers are who take the decisions about the types of innovation. As the agency theory suggests, in the utility function of a managers there are two components: tangibles and intangibles. The tangible components incorporate monetary payments and other non-monetary payments (reducing work time, bonuses, etc.). The intangible components include prestige, reputation, image, which will affect the incentives of the manager to introduce innovations. The firm does not always know both elements. So, we want to separate the motivation of managers to carry out innovation activity from the experience effect of a firm in doing the same activity along time.

The differentiation strategy –changes or improvement product innovations- produces more visible effects to the market and hence more incentives at short term

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concentration only has effects in the product equation.

to managers to engage in such strategy. The efficiency strategy –changes or some improvements in the process- have internal effects that the market is less able to observe and evaluate. In that case, managers would have less incentive to carry out such innovation. We do not have the possibility to measure that but we can control it using methods explained in the empirical analysis below.

H6: Manager will opt to introduce new products instead of new processes due to this last innovation will produce more intangible returns.

H7: Firms with more experience in developing the same innovation activity will encourage following innovating.

4. METHODS

Sample and Variables

We use information for manufacturing firms during the sample period 1990-99 from a survy called ESEE provided by the Spanish Ministry of Science and Technology.

Endogenous variables:

Innovation in product. It is a dummy variable that takes value 1 when firm involves in the creation of a new product, zero when not. Innovation in process. It is a dummy variable that takes value 1 when firm introduces some new process innovation type, zero when not. Both variables are provided directly by the responsible of filling the questionnary to the interviewer.

Explanatory variables:

We assume that the knowledge stock is determined by using the specification of Griliches and Mairesse (1984) or Hall (1990) and implemented by other authors as Blundell, Griffith and Van Reenen (1995) or Martínez-Ros and Labeaga (2002)

$$G_{it} \ ? \ S_{it} \ ? \ (1 ? ?)G_{it ? 1} \qquad [1]$$

G evolves according to [1] where S_{it} is the R&D expenditure of firm i in period t and ? is the depreciation rate.[5] This search process story implies that the decision about

[5]We use a depreciation rate of 20 per cent. Small changes in this rate do not significantly affect the results presented below.

innovating evolves according to the indicator function [1][6]. An important issue with the knowledge stock is that it can be endogenous.[7] To account for it, G will be instrumented by its prediction (*GINST*) constructed regressing *G* on industry and time dummies, firm and market characteristics, and the past knowledge stock under the assumption that the error term is uncorrelated.

Technological opportunities of the market. There are extensive literature that capture technological oportunites using the form to appropriate the returns of doing innovation. Patents are a good measure of appropriability so we include them in two ways. We use two dichotomy variables (*REGPATES*) and (*REGPATEX*) which take value 1 when firm registers a patent in Spain or in Foreign, respectively. Additionally, we include the industries dummies.

The size of firms will be measured using the logarithm of the number of employees at the end of December (*LEMP*). Since it could be negative effects of size on innovation activity we account for them assuming a non-linear relationship between size and innovation and we introduce the number of employees squared (*EMP2*) among the explanatory variables of the model (Pavitt, Robson and Townsend, 1987). This allows us to identify different size effects at different firm sizes. We use a relative measure of size (*EVOLCUOT*) that takes value 1 when firm considers an improvement in its market share.

We use as a proxy for physical capital *(KSA)* the ratio of sales to fixed assets of the firm and it is constructed using the traditional literature about the measurement of capital stock (Blundell *et al*. 1992).[8] A higher value of the ratio means that the production process is relatively more capital-intensive.

We measure the intensity of the market competition (*AVGMBE*) in an inverse way (do in a direct way by doing 1/AVGMBE), by the average gross profit market of the industry in order to capture, whether market competition encourages innovation activity. With this measure we try to avoid the possible endogeneity bias of the concentration variable.

Managerial ability. We control time invariant firm effects in the models estimated using the panel data. The unobserved effects controlled for when using the panel nature of the data would be recovering managerial ability (manager's

[6]Alternatively, we could assume that the knowledge stock is obtained using number of patents or number of innovations as in Blundell *et al.* (1995).
[7]In Martínez-Ros (2000) there is an explanation of this effect.
[8]It measures the replacement value of the firm's machinery capital stock.

experience), firm experience in doing R&D activities, or ability in internal organisation, which may affect the production of innovations.

Control variables:

A characteristic of the market that may affect both innovation activities is the growth of demand (Schmookler, 1966). A dummy variable *RECES* is defined which takes the value of 1 when the market of the firm is in a recession and 0 otherwise. We expect that a recessive demand discourage the production of whatever innovation activity.

Production processes may also be differentiated in terms of the degree of vertical integration (*CISP*). As firms internalise more activities there are more opportunities to innovate, *ceteris paribus*, and probably there are more incentives to do it if the results of innovation can be spread over several activities. Although little quantitative work has been done in this area, some case studies suggest the presence of economies of scope to R&D in vertically integrated industries. Malerba (1985) studied the life cycle of technology in the semiconductor industry and found that the advantages of vertical integration for innovative activity had varied along the cycle. *CISP* is measured, inversely, by the ratio of purchases to other firms divided by the total value of production, both variables defined in a yearly basis.

We also consider possible discipline effects of conducting export activities. We define a dummy variable (*DEXP*), which takes the value of 1 when the firm exports and 0 otherwise (in any period or in all periods. We expect that doing exports favour at least product innovation, as their presence in foreign markets may require more innovations in order to be competitive. But it is also true that firms with more innovation activity may have more incentives to export since they also have more intangible resources to sustain growth. So, no clear direction of the causality may be established.

Foreign ownership is a dummy variable (*CAPEXT*) to indicate whether firm is controlled by 50 per cent or more. This is a control variable for which no clear sign can be expected from the theory. However, depending of the origin of the external capital we expect a positive effect at least in the process innovation equation. This variable also tries to proxy a disciplinary effect of competitiveness.

Finally, we control possible shocks common to all industries using time dummies, as well as time invariant industry shocks.

Methodology

Before presenting the empirical specifications we are interesting in estimating, our first task consist in an extensive descriptive analysis of the frequencies of both innovation activities, conditioning on past events but unconditional to other possible determinants. Figures presented in Table 1 try to shed some light into the persistence of the activities at the firm level. We calculate the probability of doing product or process innovation for each firm in the current period and whenever they have conducted previously these activities. The first block in the table shows the probability of making some product innovation. The first column present the unconditional probabilities for the period 1991-99. Columns 2, 3, 4 and 5 provide the product innovation frequencies in t given the firms also made some product innovation in $t - 1$, $t - 2$, $t - 3$, and $t - 4$, respectively. When calculating all these frequencies for every period, we also try to show possible business cycle effects. The jumps from unconditional to conditional probabilities range from 117 to 168 per cent. In other words, while the percent of non-innovating firms in 1991 is more than 70 per cent, they reduce to 40 per cent among those firms doing product innovation in 1990. Experience of firms in developing this activity in the recent past seem to be a good predictor of current innovation frequencies. We summarize the information in Table 1 in Figure 1.

The increases in innovation frequencies when we extend the conditioning set to additional past events are not as espectacular as before. For instance, the innovating frequency in 1992 for firms innovating both in 1990 and 1991 is 69 percent, which must be compared with the unconditional frequency of 65 percent. On the other hand, these last figures are much less affected by cycle effects. It seems that once a firm has incurred in some sunk costs (development of an R&D unit, acquisition of capital, etc.) the continuation of these activities is less costly. Another message we can extract is that innovation is an activity that requires some experience and once a firm has acquired it, there is a significant reduction in the probabilities of moving out. The contribution to increases and decreases come from firms without experience who are continuously taking entry and exit decisions. This simple exercise poses some confidence about the fulfillment of H7 in the product innovation decision.

The second block in Table 1 presents the probabilities of making process innovation. Again, we report unconditional and conditional probabilities. The first column present the unconditional probabilities for 9 years of the sample. Columns 2, 3, 4 and 5 provide the process innovation frequencies in *t* given firms also made some process innovation in *t – 1*, *t – 2*, *t – 3*, and *t – 4*, respectively. The unconditional probabilities seem to be more affected by the business cycle than those of product innovation. The recession began at the end of 1991 and there is a big decrease in the frequency of developing new processes than in conducting product innovations. The level of innovation got by firms during the early ninetines, again recovers after 1996 when the economy began a new boom. The increases in the conditional probabilities are not as big as in the case of product innovations, because the point of departure is different. However, the implications from these figures are again that experience of firms in developing process innovations in the recent past seem to corretly predict current innovation frequencies. We present in Figure 1 the unconditional and conditional probabilities.

When extending the conditioning set to previous events we get the same picture as before. The innovating frequency in 1992 for firms innovating both in 1990 and 1991 is 68 percent, which must be compared with the conditional frequency of only doing innovation in 1991 of 64 percent. The preliminary implications from all these figures is that recent previous experience strongly conditions current performance. Again, cycle effects are affecting less the change in the decisions of firms already innovating. Although with the caution that we do not include additional conditionings, this descriptive statistics allows us to confirm H7 in the process innovation decision.

The second exercise we make consist in deriving an specification for the production of innovations, having in mind that we only observe whether the decisions are taken or not. In these circumstances, discrete choice models for the two indicators seem to be adequate. The specification proposed is:

Probability (Innovate) = f (explanatory variables, control variables, time dummies, industry dummies)

where all variables in *f(.)* are expressed in *t-1*. In cases where we exploit the full nature of the panel, we also include in the previous specification the individual non-time variant effects, which can approximate firm effects associated to manager´s expertise or ability. In order to test the different hypotheses we posed in section 3, we estimate three different static models. The first estimation is done on the whole sample and it uses the pooled data. This means that we do not control for different effects across firms. The second model is just a probit on the pooled data, but it is estimated on the sub-sample of firms innovating in the recent past (last year). So the equation is:

Probability (Innovate t / Firm innovating t - 1) = f (explanatory variables, control variables, time dummies, industry dummies)

which allows us to test whether persistence in conducting innovation activities has any effect on the rest of conditionings. The third model allows for firm specific differences according to a common distribution, i.e., discrete choice random effects model. The effects of controlling individual heterogeneity on the two equations (product and process innovation decisions) serve as a proxy for testing H6. We also estimate the same three specifications with the inclusion of the lagged indicator in order to put more confidence on the likelihood of the tests for H6 and H7.

5. RESULTS AND DISCUSSION

In Table 2 we present the naïve estimates corresponding to pooled probit models with the two different samples mentioned. In Table 3 we present the unconditional and conditional random effect probit models. Finally, Table 4 shows the coefficients of dynamic random effects probit models with the lagged indicator of the own and alternative innovation decisions included. Comparisons among unconditional and conditional coefficients within the same table provides us a first test on H7.

It seems that H7 is confirmed when looking at results in Table 1. Once we use the sample on past innovators, most of the conditionings loss their significance. But, we must be cautious because we miss differences amongst firms in these specifications. Comparisons among coefficients in Table 2 seem to confirm previous evidence, with more emphasis in the process innovation equation, being the control of heterogeneity among firms more important for product development, thus confirming H6. Comparisons of equivalent models across tables inform about the relative importance of both effects. Finally, it is more important having experience in innovating in product for the success of future product innovations and having experience in innovating in process for the success of future process innovations, but columns 3 and 4 in Table 4 also point out some complementarities between both activities. However, this is due to spurious correlation because one we introduce the own lagged indicator, the significance of the alternative vanishes.

On the other hand, it is important to test the significance of some variables in determining innovation frequencies, even after controlling for persistence and ability. In other words, we try to confirm the hypotheses established in section 3 above. H1 emphasize the importance of doing past innovations and, as a result, once experience is controlled for either estimating the model in the sub-sample of firms innovating in the recent past or including lagged innovation indicators, the accummulated knowledge stock lacks its significance almost everywhere.

Knowledge stock and technolgical opportunities get the expected estimates confirming our hypoteses. When firm accumulates knowledge, it serves and encourages itselve to be on innovating. And it is true for both decisions. Having registered patents in the own country incentives continuing the development of both innovation activities but with more intensive in the product innovation decision since patents is a barrier and a protection from imitation.

As regards H3, the evidence we find is very interesting. First, there is a quadratic effect of size in the decision to carry out product innovation. Both small and large firms innovate more in product than medium sized firms. On the other hand, for developing process innovation size seems to play a crucial role, independently of the controls we include in the specifications. However, once we condition on the existence of past innovations, size becomes irrelevant in explaining current innovation decisions.

We also find several very robust results. First, exports and innovation decisions are highly positively correlated. It seems that competition in foreign markets induce a higher propensity to make both innovation activities. Second, the physical capital is more important in the development of process rather than product innovation, thus confirming H4.

Control of the ability of the manager seems to have some effect on the determinants of innovation, but it is anyway less important than the effect of previous experience. We must note, however that heterogeneity could be correlated with some of the explanatory variables since more skills implies more propensity to innovate, but in order to continue innovating firms need to devote more resources. These feedback effects induce correlation among skills and input variables.

In those models where we include lagged innovation indicators as proxies for experience, the results are similar to those where we estimate on the subsample of firms innovating in the recent past. However, some differences need to be emphasized and clarified. These differences arise because of several reasons. First, we loose almost 60 percent of the observations when conditioning on past events. Second, given these cut in sample size

6. CONCLUDING REMARKS

We have estimated in this paper several alternatives of discrete choice models for panel data, using a Spanish survey, the Encuesta Sobre Estrategias Empresariales for the period 1990-99. Preliminary evidence indicates that in the decisions to carry out innovations, there are different determinants (or effects) in the two equations. In fact, we find that experience or persistence in doing these activities is important, whereas other conditionings remain as crucial determinants of the innovation frequencies even after controlling for experience. Ability of the manager, as proxy by firm specific time invariant effects is another factor influencing the firm´s performance. However, we test several hypotheses and we can conclude that even in an environment of managers with high propensities to innovate and firms developing experience in conducting these activities, some particular characteristics are needed in order to have success in the innovation policy. Although the past of the innovation activities in the firm (firm experience) and the unobserved heterogeneity (manager ability) are very important determinants of the decisions we model, the internal and organization resources continue being the base to develop innovation activities.

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Table 1. Unconditional and conditional Innovation Frequences

	iprod	iprodt1	Iprodt2	iprodt2t1	iprodt3	iprodt3t1	iprodt4
z90	0,187						
z91	0,271	0,589					
z92	0,271	0,644	0,529	0,715			
z93	0,258	0,627	0,594	0,718	0,487	0,786	
z94	0,269	0,665	0,58	0,746	0,541	0,754	0,5
z95	0,255	0,628	0,583	0,734	0,553	0,785	0,521
z96	0,266	0,714	0,605	0,801	0,583	0,846	0,534
z97	0,274	0,699	0,652	0,774	0,605	0,839	0,554
z98	0,271	0,672	0,617	0,744	0,585	0,778	0,577
z99	0,274	0,692	0,589	0,759	0,588	0,835	0,574

	iproc	iproct1	iproct2	iproct2t1	iproct3	iproct3t1	iproct4
z90	0,18						
z91	0,364	0,62					
z92	0,339	0,65	0,517	0,69			
z93	0,333	0,65	0,583	0,731	0,507	0,798	
z94	0,345	0,642	0,548	0,683	0,531	0,717	0,504
z95	0,337	0,641	0,566	0,718	0,524	0,759	0,533
z96	0,333	0,666	0,547	0,728	0,522	0,77	0,491
z97	0,359	0,71	0,615	0,796	0,547	0,827	0,542
z98	0,379	0,723	0,635	0,77	0,61	0,818	0,56
z99	0,352	0,654	0,575	0,698	0,556	0,761	0,55

Table 2. Innovation Decisions[1, 2, 3]

	Unconditional Probit		Conditional Probit	
	IPROD	**IPROC**	**IPROD**	**IPROC**
Intercept	-0.746 (2.27)	-1.519 (4.78)	0.443 (0.78)	-0.534 (0.99)
KSA	0.182 (2.07)	0.813 (7.26)	0.091 (0.51)	-0.040 (0.38)
EXPORT	0.388 (12.3)	0.183 (6.17)	0.289 (4.70)	0.086 (1.60)
AVGMBE	0.007(1.32)	-0.002 (0.37)	0.010 (1.15)	-0.004 (0.50)
G	1.946 (7.00)	1.187 (4.24)	0.984 (1.81)	0.653 (1.21)
SIZE	0.033 (0.70)	0.188 (4.09)	-0.011 (0.14)	0.112 (1.39)
SIZE2	0.018 (3.69)	-0.000 (0.09)	0.011 (1.35)	0.005 (0.65)
EVOLCUOT	0.149 (5.45)	0.224 (8.65)	0.037 (0.76)	0.160 (3.64)
REGPATES	0.468 (8.65)	0.272 (5.07)	0.170 (2.16)	0.155 (1.92)
REGPATEX	0.288 (4.18)	0.051 (0.74)	0.138 (1.39)	0.036 (0.36)
RECES	0.025 (0.82)	-0.049 (1.63)	0.102 (1.76)	-0.013 (0.24)
CAPEXT	-0.044 (1.31)	0.008 (0.30)	-0.096 (1.64)	0.047 (0.90)
CISP	-0.002 (0.41)	0.003 (0.68)	-0.009 (0.97)	0.006 (0.73)
LR[4]	6877.21 (37)	7775.50 (37)	2089.73 (37)	2654.47 (37)

Notes.
1. Sample sizes are 13225 observations in the unconditional models and 3464 and 4420 observations in the conditional product and process innovation equations.
2. In all specifications we include additional controls as time and industry dummies, the knowledge stock and spillovers indicator.
3. T-statistics (in absolute value) are in parenthesis.
4. LR is the likelihood ratio test (degrees of freedom in parenthesis).

Table 3. Innovation decisions[1, 2, 3]

	Unconditional Random Effects Probit		Conditional Random Effects Probit	
	IPROD	**IPROC**	**IPROD**	**IPROC**
Intercept	-1.192 (2.48)	-1.711 (4.04)	0.633 (0.93)	-0.426 (0.71)
KSA	0.307 (2.57)	0.571 (4.32)	0.146 (0.66)	-0.039 (0.33)
EXPORT	0.313 (5.64)	0.167 (3.58)	0.260 (3.27)	0.079 (1.24)
AVGMBE	0.008 (1.20)	-0.001 (0.26)	0.017 (1.60)	-0.003 (0.38)
G	1.039 (2.46)	0.760 (1.87)	1.040 (1.49)	0.602 (0.94)
SIZE	0.006 (0.06)	0.223 (2.54)	0.011 (0.10)	0.090 (0.92)
SIZE2	0.026 (2.40)	0.003 (0.34)	0.013 (1.14)	0.009 (0.91)
EVOLCUO	0.076 (2.00)	0.143 (4.28)	0.021 (0.36)	0.160 (3.26)
REGPAT	0.349 (4.66)	0.230 (3.26)	0.203 (2.13)	0.183 (1.99)
REGPATX	0.201 (2.13)	0.042 (0.46)	0.101 (0.85)	0.052 (0.45)
RECES	0.029 (0.67)	-0.068 (1.78)	0.156 (2.25)	-0.017 (0.29)
CAPEXT	0.017 (0.25)	0.044 (0.76)	-0.098 (1.25)	0.067 (1.05)
CISP	-0.004 (0.59)	0.003 (0.54)	-0.015 (1.38)	0.005 (0.58)
LR[4]	5867.36 (37)	7002.34 (37)	2039.97 (37)	2628.48 (37)

Notes.

1. Sample sizes are 13225 observations in the unconditional models and 3464 and 4420 observations in the conditional product and process innovation equations.
2. In all specifications we include additional controls as time and industry dummies, the knowledge stock and spillovers indicator.
3. T-statistics (in absolute value) are in parenthesis.
4. LR is the likelihood ratio test (degrees of freedom in parenthesis).

Table 4. Innovation decisions[1, 2, 3]

	Dynamic Random Effects Probit (own lag)		Dynamic Random Effects Probit (alternative lag)	
	IPROD	**IPROC**	**IPROD**	**IPROC**
Intercept	-1.238 (2.89)	-1.437 (3.79)	-1.106 (2.32)	-1.809 (4.32)
IPROD(-1)	0.984 (24.4)			0.357 (9.65)
IPROC(-1)		0.896 (25.8)	0.279 (7.45)	
KSA	0.200 (1.79)	0.279 (2.22)	0.239 (2.00)	0.548 (4.15)
EXPORT	0.275 (6.01)	0.137 (3.49)	0.300 (5.45)	0.141 (3.08)
AVGMBE	0.005 (0.85)	0.001 (0.25)	0.009 (1.32)	-0.002 (0.37)
SIZE	0.020 (0.27)	0.165 (2.48)	-0.008 (0.08)	0.234 (2.75)
SIZE2	0.015 (1.88)	0.000 (0.01)	0.025 (2.34)	0.000 (0.01)
EVOLCUO	0.068 (1.96)	0.150 (4.82)	0.068 (1.82)	0.137 (4.10)
REGPAT	0.240 (3.50)	0.170 (2.63)	0.335 (4.50)	0.174 (2.48)
REGPATX	0.228 (2.62)	0.041 (0.50)	0.203 (2.16)	0.032 (0.36)
RECES	0.014 (0.35)	-0.063 (1.78)	0.026 (0.60)	-0.071 (1.86)
CAPEXT	-0.026 (0.49)	0.022 (0.47)	0.019 (0.28)	0.037 (0.65)
CISP	-0.002 (0.29)	-0.000 (0.01)	-0.004 (0.71)	0.004 (0.62)
LR[4]	5589.28 (38)	6687.97 (38)	5839.68 (38)	6956.09 (38)

Notes.
1. Sample sizes are 13225 observations in all models.
2. In all specifications we include additional controls as time and industry dummies, the knowledge stock and spillovers indicator.
3. T-statistics (in absolute value) are in parenthesis.
4. LR is the likelihood ratio test (degrees of freedom in parenthesis).

Figure 1. Product Innovation and Firm Experience

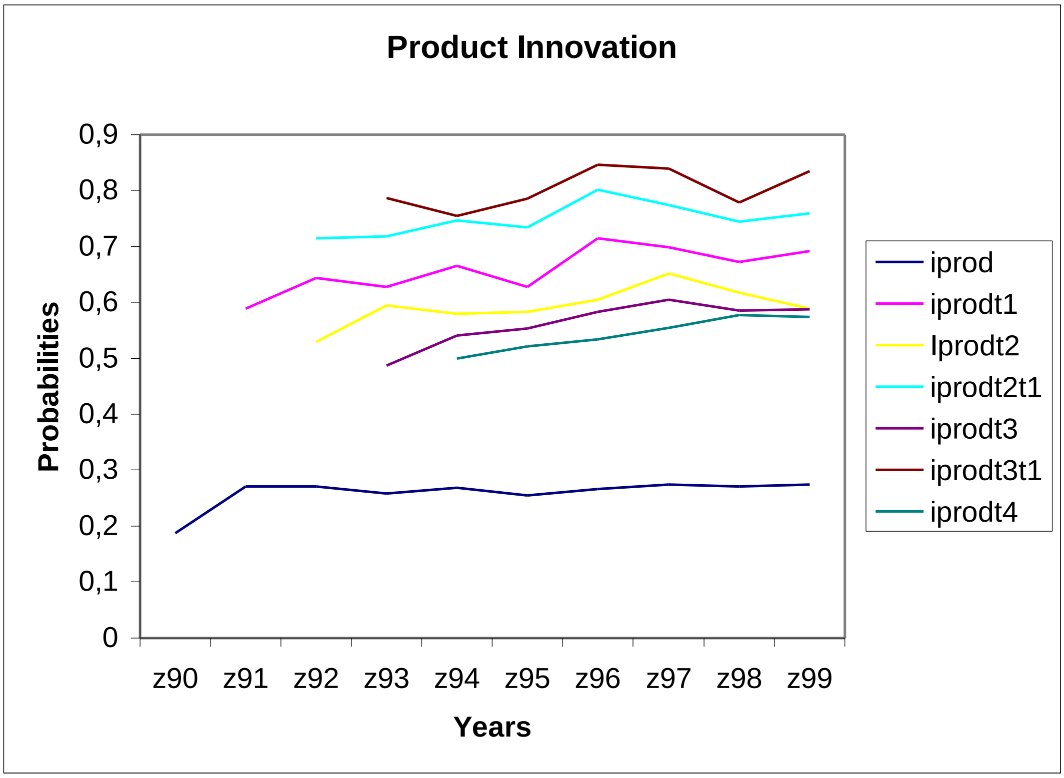
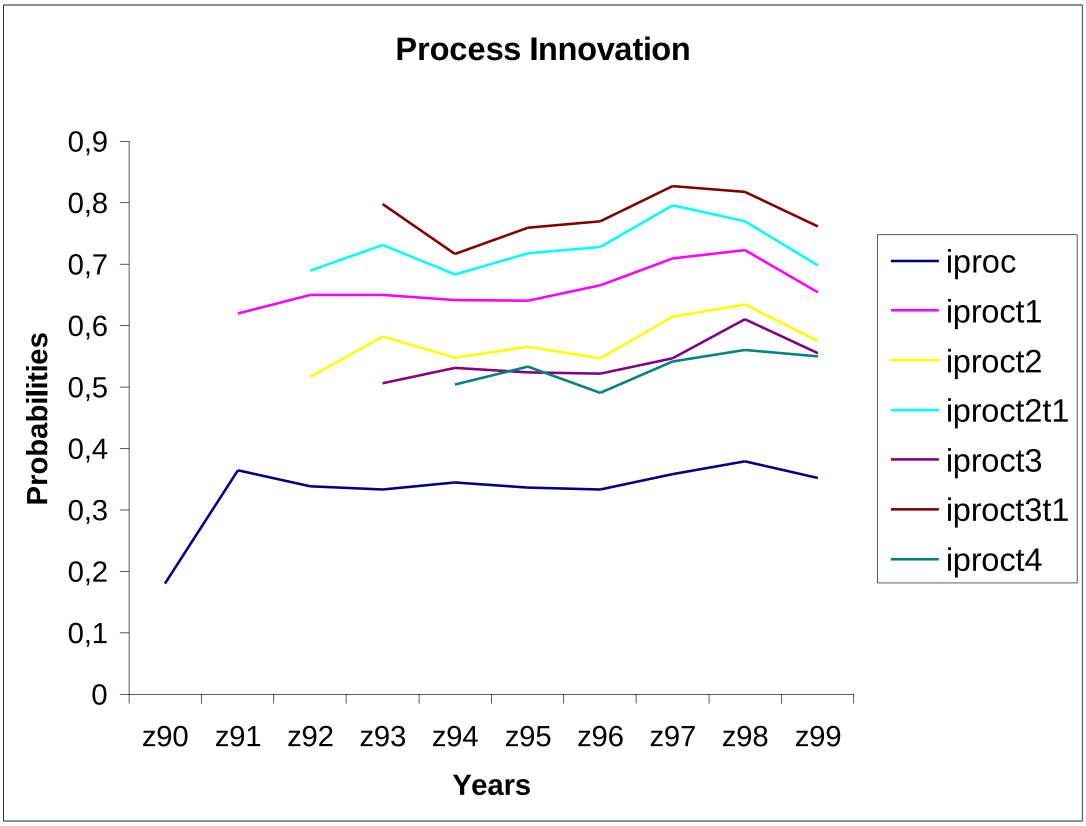


Figure 2. Process Innovation and Firm Experience



Data Appendix

The database is provided by the Spanish Industry and Energy Ministry and involves approximately *18000* firms followed along the period 1990-99 and belonging to the manufacturing sector. The sample we use consists in aproximatedly *1000* firms that have provided information in the full period. In that sense, we have a complete panel data. The descriptive statistics of the main variables are in Table A.1.

Table A.1. Descriptive statistics of the main variables

	PRODUCT INNOVATION		**PROCESS INNOVATION**	
	MEAN	**STD. DEV.**	**MEAN**	**STD. DEV.**
G	0.025	0.048	0.020	0.042
EXPORT	0.764	0.425	0.711	0.453
KSA	0.046	0.131	0.061	0.171
CAPEXT	0.304	0.460	0.303	0.459
SIZE	4.824	1.635	4.819	1.594
AVGMBE	2.455	14.781	1.377	15.111
RECES	0.232	0.422	0.216	0.412
EVOLCUOT	0.369	0.483	0.375	0.484
CISP	64.255	15.08	63.204	15.806
REGPATES	0.147	0.354	0.107	0.310
REGPATEX	0.093	0.291	0.068	0.251
Observations[1]	4701(26 %)		6008 (33.23%)	

Notes.

1. Sample in each innovation type corresponds to the observations in the period 1990-1999. In brackets are expressed the percentage over the total number of observations.