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A DYNAMIC ANALYSIS OF INTRAFIRM DIFFUSION: THE ATMs

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1. INTRODUCTION

Technological progress fundamentally depends on the adoption of new technologies. However, firms neither immediately nor fully adopt them. The speed and the extent at which new technologies diffuse in the market has been the subject of study by economists and marketing and management practitioners for many years. The development of new products/processes and the capacity of firms to innovate have been pointed as areas of future interest to marketing researchers (Kerin, 1996; Malhotra, 1996 and Malhotra *et al.* 1999). They constitute fundamental competitive instruments for the success and survival of firms.

From a microeconomic perspective, two questions are central to the diffusion debate: (1) What factors influence the adoption of new technologies by the firms operating in a market? And(2), what are the factors that influence the speed with which firms tend to fully employ the new technology once they have adopted it? Whereas the first question refers to the interfirm rate of diffusion of new technologies and has been a frequent topic of research, much less attention has been paid to the study of the intrafirm rates of diffusion. This is surprising, given that the study of the extent of use of a technology within a firm is at least as important as the study of the number of users of that technology (Stoneman, 1981).

The importance of covering this gap in the literature should be emphasised. Given that the great majority of the innovations are divisible, the initial adoption decision constitutes just the first step in a more complex and longer diffusion process by which the potential beneficial effects of a new technology are fully realised to the benefit of society. As Stoneman (1981) points out, this is specially important in a world populated by large firms, in which the initial adoption decision only supposes a small percentage in aggregate terms. This is, in fact, the case in most of the latest technologic advances (microcomputers, mobiles, automated teller machines or teleprocess terminals) associated with information processing needs.

In this paper, we provide evidence on the factors affecting the speed at which new technologies diffuse within firms. We put special emphasis on Schumpeterian hypothesis related to the effect of firm size and market structure, namely, (1) that there is a positive relationship between market concentration and innovation and (2) that large firms are more innovative than their smaller counterparts (Kamien and Schwartz, 1982). Our results confirm the importance of both market structure and firm size when explaining intrafirm diffusion. Their effect is, however, different from the one hypothesised by Schumpeter. Both market concentration and firm size are shown to have a negative and significant influence on the time from adoption to full internal diffusion. The relevance of other factors on the time of diffusion is also analysed through the use of survival analysis methods. Although this methodology has been applied to the study of adoption probabilities, no attempt has been made to evaluate the factors affecting the time elapsed from adoption to full internal diffusion. As Karshenas and Stoneman (1995) suggests, if different states in the internal adoption process are defined, duration models may be used to estimate the time up to a concrete level of adoption. Following this recommendation, a proportional hazards model is employed to evaluate our hypotheses.

In order to test the predictions suggested by the theory, we examine the characteristics of the diffusion of a new product and process technology, the automated teller machine, on a sample of Spanish savings banks. This technology has been the subject of several studies (Hannan and McDowell, 1984a, 1984b, 1986; Ingham and Thompson, 1993; Maudos, 1994; Saloner and Shepard, 1995). However, no attempt has been made to consider its intrafirm diffusion aspects.

The data available for the analysis possesses two important features that are relevant for our analysis. First, as in Ingham and Thompson (1993), the sample we consider is relatively homogeneous in terms of resources and capabilities, which has been suggested as an interesting feature in view of the investigation of firm level effects. Second, the Spanish banking sector has been subject to changes that have affected the configuration of the sector in terms of the behaviour of the financial entities and the structure of the market. The elimination, in 1989, of the restrictions that prevented savings banks from operating all over the country has transformed the context in which they perform their activities. As a consequence, the wave of mergers and acquisitions that took place and the expansion process that led some financial entities to open new branches in new geographical markets is expected to have influenced innovation and diffusion rates. The possibility of delimitation of the geographical market in which a savings bank operates provides us with interesting data on which to perform our analysis.

The paper is organised as follows: Section 2 reviews the literature on intrafirm diffusion, distinguishing between those modelling efforts that have been based on the epidemic tradition and those more reliant on a decision-theoretic approach. Section 3 proposes the set of hypotheses that are tested. Emphasis is made on size and market structure factors. Section 4 presents the dynamic market potential model that is used to estimate the rates of intrafirm diffusion and explains the econometric strategies followed. Section 5 describes the sample of Spanish savings banks on which the analysis is performed. Section 6 shows the results of the estimation of the ordinary models and survival regression models proposed and, finally, Section 7 concludes.

2. LITERATURE REVIEW

Microeconomic research on the factors affecting the diffusion of new technologies has concentrated on the analysis of two main dimensions, namely, interfirm and intrafirm. The first of these has been concerned with the study of the number of firms using an innovation and has been the subject of frequent theoretical and empirical attention. On the other hand, the intrafirm dimension has concentrated on measuring the extent at which a firm uses a new technology once the initial adoption decision has been taken. Contrary to the interfirm case, activity has been much less both theoretical and empirically and has focused on the effect of demand factors. This Section reviews the theoretical and empirical literature in the intrafirm tradition.

A. Theoretical literature.

For the purpose of our discussion, the theoretical literature on intrafirm diffusion may be divided into two groups of models: Epidemic Models and Decision-Theoretic

Models of intrafirm diffusion. The main difference between both approaches is that the latter is more explicitly choice-theoretic. As the diffusion process develops, the experience of firms with new technology leads them to update initial estimates of both risk and returns and the level of use of the new technology (Karshenas and Stoneman, 1995). Both perspectives are analysed in the following discussion.

A.1. Epidemic Models of intrafirm diffusion.

The first group of theoretical models belongs to a type of models called "epidemic", given their similarities with the ones which study epidemics in biology. Although they have mainly been used in the analysis of the interfirm dimension of diffusion, some applications are also found in the intrafirm case. The most important hypothesis underlying these models is that the rate at which an innovation diffuses is directly proportional to the gap existing between the number of potential adopters and the cumulative number of adoptions. This assumption is consistent with the traditional finding of a S-shaped diffusion curve characteristic of most diffusion studies.

That is, the "fundamental diffusion model" (Mahajan and Peterson, 1985) is defined as :

$$\frac{dN(t)}{dt} = g(t)\left[\overline{N} - N(t)\right] \quad (1)$$

where $(dN(t)/dt)$ is the rate of diffusion at time t, g(t) is the coefficient of diffusion, which includes the factors determining the decision on the extent of use of the new innovation, N(t) is the cumulative number of adopters at time t and $\overline{N}$ is the total number of potential adopters in the social system.

Three particular cases are distinguished from the general one, depending on the form assumed for the coefficient of diffusion, g(t) (Mahajan and Peterson, 1985). The *external influence model* assumes diffusion to be driven by factors outside the social system, that is g(t)=a. The model is more appropriate in situations characterised by a low degree of interaction between the components of the system and in which the main flows of information are provided by external and structured sources of communication (e.g.: government agencies, salespeople...). In the *internal influence model*, the diffusion process is exclusively explained by interpersonal contacts. In this case, the coefficient of diffusion takes the form g(t)=bN(t). That is, the rate of diffusion is explained by the interaction of three elements: prior adopters (represented by N(t)), potential adopters at time t ($\left[\overline{N} - N(t)\right]$) and an index of imitation (b). Finally, a last type of models, *mixed-influence models*, attempt to combine both internal and external effects through the inclusion of a coefficient of diffusion that takes a more complex form ($g(t) = (a + bN(t))$).

These epidemic type models are based on several assumptions which are not always realistic and have been criticised by several authors. As Davies (1979) points out, epidemic models of diffusion assume the absence of formal internal information mechanisms within firms. Nevertheless, if those mechanisms do exists (as is generally expected), once the firm receives a piece of information the whole firm would have access to it. Therefore there would be no need to rely on an epidemic model in order to explain diffusion (Stoneman, 1983). The main criticisms, however, are based on the lack of microeconomic foundations in their development (Stoneman, 1981). In spite of these objections, research efforts have mainly concentrated on designing a number of modifications that incorporate extensions to the basic models. Examples include models that incorporate a dynamic ceiling on the maximum number of adopters (Mahajan and Peterson, 1978), flexible diffusion models (Floyd, 1968) or models that integrate both the spatial and time dimension in their analysis (Mahajan *et al*., 1979).

Mansfield (1963) is the first author to propose a specific epidemic type model directed to study the intrafirm dimension of the diffusion process. He uses a pure internal influence model, assuming that the coefficient of intrafirm diffusion is affected by a set of factors considered to be relevant. In his model, the profitability of the new technology and the liquidity of the firm are expected to have a positive effect on the rate at which the process of intrafirm adoption is fully completed. On the other hand, uncertainty and firm size are expected to be inversely related to the rate of intrafirm diffusion. Mansfield makes the level of uncertainty further depend on two additional factors: the time elapsed from the moment in which the first firm in the industry adopted the innovation and the level of fulfilment of the adoption process within the firm at time t. Both factors have a negative influence over the level of uncertainty associated to the innovation. The more time the innovation has been in use by other firms and the more advanced the process of internal diffusion, the less the uncertainty supported by the firm.

A.2. Decision-Theoretic Models of intrafirm diffusion.

Despite the empirical success of epidemic type diffusion models, they have been questioned by several authors. As we have mentioned, Mansfield's work on diffusion has been criticised by Davies (1979) and Stoneman (1981) for lacking a solid microeconomic modelling of the process of decision making within the firm. Following Feder *et al.* (1985) a theoretical framework for analysing adoption and diffusion processes at the firm level should include a model of the entrepreneur's "*decision making about the extent and intensity of use of the new technology at each point ... and a set of equations of motion describing the time pattern of parameters that affect these decisions"*. These equations of motion should incorporate changes in the model parameters over time, resulting from dynamic processes affecting information levels, learning by doing or credit access.

To some extent, some of these criticisms have been overcome by work that has modelled the process of decision making under uncertainty (Stoneman, 1985). These models have mainly been developed in the context of the adoption of agricultural innovations in developing countries. Most of the papers have used static analysis, relating the degree of adoption to the factors that affect it (Feder *et. al.*, 1985), and have followed Mansfield's work in characterising the problem as one in which a new technology substitutes the old one.

A small number of these papers have focused on the effect of learning and new information on the intrafirm diffusion process. Lindner *et al.* (1979) is an example in which a Bayesian mechanism is used to achieve such an objective. A version of this type of models has been developed by Stoneman (1981) for the case of industrial innovations. Contrary to Mansfield, he proposes a choice of technique-theoretic model in which the level of full adoption is determined endogenously. The model is shown to have the characteristic S-shape form found in diffusion studies and it is consistent with Bayesian learning.

According to these models, the entrepreneur decides between the old and the new technology by maximising a utility function in which the firm incurs the cost of adjustment every time the internal level of adoption is changed. As in the previous studies, risk and profitability are key elements. Initially, the firm sets out with an estimation of risk and returns stemming from the new technology. As diffusion proceeds the entrepreneur learns from experience with the new technology, adjusting the expected returns and better estimating the risk supported.

The pace at which internal diffusion takes place is positively influenced by profitability. The rate of intrafirm diffusion is higher the larger the anticipated return from the new technology and the lower adjustment costs. Contrary to Mansfield, the model predicts a positive effect of uncertainty on intrafirm diffusion in the case where, as is generally expected, the correlation between the returns to the new and old technologies is negative (Levin *et al.*, 1992). Other factors affecting the diffusion path are firm attitudes to risk and the covariance of returns between the old and the new technologies.

B. Empirical literature.

In a similar vein, the empirical literature on the determinants of intrafirm diffusion has been scarce and mainly dominated by the application of models of the epidemic type. The interest has centred on the study of the factors that explain the S-shape and affect the speed of intrafirm diffusion. Mansfield (1963) applies the model to the study of the speed of substitution of steam locomotives for diesel ones in the US. The results seem to confirm the validity of the model at explaining the pace at which the new technology displaces the old one. All the variables, except the size of the firm, do have the predicted influences on the rate of intrafirm diffusion[1]. Romeo (1975) analyses the diffusion of numerically controlled machine tools in ten industries in the US. The main difference with Mansfield's study is that internal diffusion is measured through the percentage of total purchases of new machine tools that were of the new type. In this case, firm size and uncertainty are shown to have the predicted influences over the rate of intrafirm diffusion. Taken together, the evidence seems to confirm the hypothesis of the model and to point out that the processes of interfirm and intrafirm diffusion share common features (Mansfield, 1963).

This evidence is complemented with a more descriptive analysis presented in two additional studies. Nabseth and Ray (1974) analyse the internal diffusion of special presses in paper making at both the plant and firm level. Their main conclusion is that expected profitability plays a very important role at explaining intrafirm diffusion. By using data from 19 steel plants, Schenk (1974) finds the rate of intrafirm diffusion of continuous casting to be negatively affected by firm size. Globerman (1976) studies the effect of firm size and year of adoption on the number of years it took for one hundred percent of a firm's output to be produced on machines equipped with special presses[2]. The estimated relationship is consistent with the Mansfield model and shows that both firm size and year of adoption do have the expected effects on the time to full internal diffusion.

Antonelli (1985) studies the internal diffusion of technology in an international context. Firm size is, again, negatively related to the rate of intrafirm diffusion. The time lag of adoption, a centralised structure and the internal origin of the innovation present a positive influence on diffusion. Similarly, Polo (1987) uses the model proposed by Mansfield (1961) in order to analyse the internal diffusion of teleprocess terminals in the Spanish banking sector. The results for the sample of banks and savings banks confirm previous empirical findings in relation to the influence of firm size and the time lag of adoption over intrafirm rates.

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[1] Mansfield also tests the influence of the following factors: age of the old locomotives, absolute number of locomotives necessary to go from a 10% to a 90% of intrafirm diffusion, average haul of the railroad and firm profitability.

[2] Other factors considered were the average age of the machines in place, the proportion that newsprint comprised of total output, the number of paper machines operated by the firm and firm ownership status.

The last study considered in this review is the one by Levin *et al.* (1992). The distinguishing feature of their research is that they attempt to investigate the structural factors of markets affecting the intrafirm rate of diffusion. Together with some of the variables already included in other studies, they examine the effect of market concentration on the internal adoption of optical scanners through the stores of firms located in different geographic markets across the United States. The results confirm that intrafirm diffusion takes place more rapidly when the profitability of the innovation is greater and the costs are lower. Market concentration and firm market share have a negative effect on the speed of internal diffusion, confirming the effect of uncertainty hypothesised by the Stoneman choice-theoretic model. Store size and order effects positively influence the diffusion process, whereas the presence of key rivals in the market has a negative impact. Finally, in agreement with previous research, the size of the firm is shown to be negatively related to the rate of intrafirm diffusion.

3. HYPOTHESES

The hypotheses that are tested in this paper are limited by the characteristics of our sample and the availability of data. They draw on the literature on innovation and new technology diffusion and, specifically, on the papers reviewed in the previous section. Accordingly, the hypotheses proposed refer to the innovation, the firm and the market in which it operates.

Expected profitability and uncertainty surrounding the innovation.

Expected profitability and uncertainty are common elements of models that study investment behaviour of firms. In consequence, these two components are also present in both the epidemic and the choice-theoretic modelling of the intrafirm diffusion process. All the models assume that an innovation will appear more attractive to a firm the higher the expected profitability from using it. Given this, the main concern of researchers has centred on either finding a way of correctly measuring this concept, or choosing an appropriate proxy for it. The main difference on the role of profitability between the two approaches reviewed before is, again, in terms of the degree of formalisation of the decision process within the firm. Mansfield's work assumes the relationship between profitability and the rate of intrafirm diffusion to be true, whereas Stoneman's derives the positive relationship from his choice of technique model.

Much less agreement is found in the theoretical literature when the effect of the uncertainty surrounding the innovation is studied. It is the fact that almost any investment is, at least, partially irreversible what makes uncertainty so relevant (Pindyck, 1991). Examples include situations in which the investment happens to be firm or industry specific or cases in which once the investment is realised the resale price falls far below the costs incurred. Provided that strategic factors do not compel the innovator to quickly spend money in acquiring the innovation, the effect of uncertainty may be reduced by the option the firm has to wait for new information to arrive. As hypothesised by the epidemic models reviewed before, this information may be seen arriving from either sources of information originated in the social system in which the diffusion process is taking place or from external channels of communication. According to this, we would expect the firm would delay adoption whenever uncertainty is high and/or a substantial reduction of it is expected in the following period. Nevertheless, when strategic aspects are important, this option to delay investment may not be so feasible and pre-emption may a more relevant issue to consider.

As in the case of profitability, both epidemic and decision models consider uncertainty an important factor at the time of explaining the rate of intrafirm diffusion of an innovation. In this case, however, opposite effects are proposed. Whereas Mansfield's predictions are negative, the influence of uncertainty on intrafirm diffusion in Stoneman's model is positive (Levin, *et al*., 1992). The empirical evidence (Mansfield, 1963; Romeo, 1975; Levin *et al*., 1992) shows that the reduction of uncertainty is positively related to diffusion, at least when the time elapsed from the moment in which the first firm in the industry adopted the innovation is considered. According to this, we should expect the delay in adoption to positively influence the rate of intrafirm diffusion. This will be the effect hypothesised in this research.

Therefore, our first set of hypothesis is enunciated as follows:

Hypothesis 1: *the profitability of the innovation is expected to have a positive effect on the rate of intrafirm diffusion*.

Hypothesis 2: *the reduction of the level of uncertainty surrounding the innovation is expected to have a positive effect on the rate of intrafirm diffusion*.

Firm size and fund availability.

The study of diffusion of new technologies has largely been concerned with the effect of large firm size on technical progress. This interest derives from the Schumpeterian hypothesis that "large firms are more than proportionately more innovative than small firms" (Kamien and Schwartz, 1982, pp. 22). Although it is not clear whether this effect was, in fact, proposed by Schumpeter (Cohen and Levin, 1989; Kamien and Schwartz, 1982), it has motivated a growing body of literature that attempts to check the validity of the proposition. In this context, the literature on diffusion has also concentrated in analysing the influence of firm size on the shape of the diffusion curve. The interest has been to ascertain whether large firms are quicker to adopt new technologies than small ones.

It is generally assumed that bigger firms lead the innovation and diffusion processes due to the existence of economies of scale and scope in R&D activities and in the application of their results (Buzzachi *et al*., 1995). Given that large firms have a larger volume of sales than their smaller counterparts, they are supposed to be able to spread the fixed cost invested in innovation over a higher number of units (Cohen and Levin, 1989). A second argument focuses on the existence of capital market imperfections to justify the proposed positive effect. If the availability of internal funds is higher in bigger firms they should be able to finance the investment associated with innovation and diffusion processes and engage in these activities. A similar argument is the one that points to the fact that more profitable entities are able to secure the stable need of funds required. Other authors suggest the idea that large companies are more likely to possess the specialised complementary assets required for the commercial success of innovations (Teece, 1986; Buzzachi *et al.*, 1995).

Counterarguments focus on the loss of managerial control in large firms (Cohen and Levin, 1989) and the fact that they may suffer from what has been termed structural inertia (Crozier, 1964). This would make bigger firms the slowest at diffusing the new technology. The empirical evidence for the case of the diffusion of new technologies tends to confirm a positive effect on size when the initial adoption decision of firms is considered. This evidence is specially convincing in the case of the adoption of automated teller machines in banking. Several papers (Hannan and Mc Dowell, 1984a,b,1986; Sharma, 1993, Buzzachi *et al*., 1995) prove the positive influence of firm size on the probability of adoption of ATMs. However, this positive relationship is not restricted to banking and examples are also found in the electric utility industry (Rose and Joskow, 1990) or in the engineering and metalworking industries (Baptista, 2000).

In the case of intrafirm diffusion, however, the theoretical arguments and the empirical evidence point in the opposite direction. Firm size is expected to have a negative effect on the rate of diffusion when the analysis centres on the rate at which diffusion proceeds internally. Romeo (1975) indicates two reasons for this effect. First, the absolute level of investment necessary to achieve a concrete degree of internal diffusion is lower in smaller firms. Second, processes of decision-making may be slower in bigger firms. This second reason seems to be along the lines of some of the counterarguments mentioned before for the case of the interfirm diffusion. The empirical evidence (Romeo, 1975; Globerman, 1976; Levin *et al*., 1992) shows, in fact, that this negative effect is in operation when intrafirm aspects are considered.

Another difference with the literature of interfirm diffusion is that economies of scale and scope and market imperfection arguments are analysed separately. Therefore, whereas firm size is expected to have a negative effect on the rate at which innovations diffuse internally the availability of financial resources is expected to have a positive influence. This positive effect seems to have been confirmed empirically. Both Romeo

(1975) and Mansfield (1963) find a positive effect of liquidity on the rate of intrafirm diffusion. According to this, in this paper we attempt to discern between these two competing effects. Therefore, following our previous discussion, our third and fourth hypotheses take the following form:

Hypothesis 3: *firm size is expected to have a negative effect on the rate of intrafirm diffusion*.

Hypothesis 4: *the availability of financial resources is expected to have a positive effect on the rate of intrafirm diffusion*.

Market structure.

Together with firm size, the relationship between market structure and innovative behaviour has been one the main concerns for economists and policy makers. As in the case of the previously analysed variable, Schumpeter suggests a positive relationship between market concentration and innovative activity. The possibility available to the innovator to exert market power would provide him with the incentives to undertake the investment required. From a theoretical perspective, the models and hypothesis that have been developed in order to analyse the different aspects of the relationship do not provide us with radical conclusions. As Hannan and McDowell (1984a, pp.330) point out, in a technology adoption context, perhaps the best description of the existing knowledge about this relationship appears to be that it is, at best, a "complex one" and "contingent on circumstances about which there may be little information in any empirical application".

Some authors propose that this positive influence of market structure on innovation is also valid for the diffusion case, although monopoly structures are explicitly excluded (Gatignon and Robertson, 1989). A more concentrated market would allow firms to better capture consumer value than a less concentrated market, providing incentives for early adoption (Saloner and Shepard, 1995). In this case, the counterargument seems to centre on the fact that this higher concentration would, however, undermine the pressures to adopt exerted by the existence of higher levels of competition[3]. Therefore, as Reinganum (1981) points out, the reasoning should attempt to reconcile the conflicting effects between the expected positive effects of competitive pressures and appropriability.

All this theoretical background is complemented with the one that suggests that the relationship between diffusion and market structure may be best captured through a quadratic specification. In fact, this quadratic relationship has been hypothesised by Kamien and Schwartz (1982) modelling of the adoption on innovations and has proved valid in a number of empirical studies investigating the link between market structure and innovation activity (Cohen and Levin, 1989; Espitia *et al*., 1991). However, the empirical evidence on interfirm diffusion also offers conflicting results. In addition to the quadratic influence, some papers find a positive relationship (Hannan and McDowell, 1984a,b; Sharma, 1993; Saloner and Shepard, 1995) and, in other cases, the relationship between market concentration and innovation adoption is shown to be negative (Romeo, 1977; Levin et al. 1987).

Arguments against and in favour of a positive relationship between market structure and the internal diffusion of innovations tend to centre on uncertainty and the pressures to adopt exerted by competition. As we have seen, the prediction of the Stoneman model regarding uncertainty is one of a direct relationship with technological progressiveness. Market concentration should reduce uncertainty, lowering intrafirm diffusion rates. In a similar vein, Mansfield (1968) points out a positive relationship between competition intensity and adoption. Following the Schumpeterian hypothesis, monopoly power should be positively related to innovation. In this case, the empirical evidence is even more scarce. In the only available study (Levin *et al*., 1992) concentration is shown to be negatively related to the rate of intrafirm diffusion of optical scanners in grocery stores. Given this, our last hypothesis takes the following form:

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[3] Quirmbach (1986) points out that in those markets where collusive behaviour takes place, diffusion will proceed more slowly. This solution seems to be more feasible in more concentrated structures.

Hypothesis 5: *market concentration is expected to have a negative effect on the rate of intrafirm diffusion.*

Table 1 summarises the hypotheses that have been proposed and will be tested in this research.

TABLE 1. HYPOTHESES AND EXPECTED EFFECTS.

Hypothesis	Expected effect on intrafirm diffusion.
H1: Expected profitability	+
H2: Uncertainty	-
H3: Firm size	-
H4: Availability of funds	+
H5: Market structure	-

4. MODEL AND ECONOMETRIC STRATEGY

4.1. The traditional approach

The empirical studies investigating on the factors affecting the intrafirm rate of diffusion have traditionally relied on a two-stage procedure (eg.: Mansfield, 1963, Levin *et. al.*, 1992). The method proceeds as follows. In the first stage, the parameters of intrafirm diffusion are estimated for every firm, given the data on the number of new units of the old technology acquired. The parameters obtained in this way are then used as the dependent variables in a second stage in which the influence of the factors highlighted in the previous Section is evaluated.

To follow this approach, a description of how the diffusion process evolves is first needed in order to obtain the parameter that gives the speed of internal adoption for each firm. To this end, researchers have generally used models of an epidemic type. The main reason seems to be the excellent results they provide in terms of goodness of fit when they are applied, together with their simplicity.

In this paper, the intrafirm diffusion process is modelled through the "fundamental diffusion model". As mentioned before, this is the epidemic internal-influence model used by Mansfield (1963) and Griliches (1957), which gives the classical logistic curve for the number of cumulative adoptions. One of the main limitations of this model for our purposes is that the maximum number of adopters is expected to remain constant throughout the diffusion process. Although this assumption could seem plausible in a relatively stable population of potential adopters, it seems unrealistic in the general case and, particularly, in our sample. We would expect the number of potencial adopters either to increase or decrease over time depending on different relevant factors.

A modification of the model that takes into account a dynamic potential adopter population has been proposed by Mahajan and Peterson (1978). Their proposal allows for changes in the maximum number of potential adopters over time. According to this, $\overline{N}$ (t), the dynamic maximum number of adopters is hypothesised to depend on a vector of relevant variables, B(t), in the following way:

$$\overline{N}(t) = f\left[B(t)\right] \tag{2}$$

Substituting (2) into the fundamental diffusion model (1) yields

$$\frac{dN(t)}{dt} = bN(t)\left(f\left[B(t)\right] - N(t)\right) \tag{3}$$

The discrete analogue to model (3),

$$N(t+1) - N(t) = bN(t)f\left[B(t)\right] - bN^2(t)$$

or

$$N(t+1) = \left(bf\left[B(t)\right] + 1\right)N(t) - bN^2(t) \tag{4}$$

may be used to estimate the parameter of intrafirm diffusion, b, as "minus" the coefficient accompanying the $N^2(t)$ regression term.

The approach followed in this paper takes expression (4) as the starting point. This discrete analogue version of the model is first used to estimate the parameter of intrafirm diffusion for each firm, b, by OLS. The estimated intrafirm diffusion rate for each firm is then used as the dependent variable in a second OLS regression (correcting for heteroskedasticity, White (1980)) in which the explanatory variables suggested by the literature are included.

4.2. Survival Analysis

In this research, a different econometric strategy is also used. We estimate a survival model of the type proposed by Cox (1972). Survival or duration models have been used in the diffusion literature to study the time up to first firm adoption of a new technology (for a recent application, see Baptista, 2000). In these models, the time from the moment in which the new technology is available in the market to first adoption is specified as a function of innovation, firm and market characteristics. No attempt, however, has been made to incorporate these techniques into the analysis of the speed at which intrafirm diffusion takes place. The use of duration models in this case seems a natural extension of their application in interfirm studies. Karshenas and Stoneman (1995) suggests that, if different states in the internal adoption process are defined (for example, in terms of percentage of share of output produced by the new technology), duration models may be used to estimate the time up to a concrete level of adoption. This would provide us with the possibility of testing the importance of different factors in different stages of the internal diffusion process.

The model that will be used in this research is the Proportional Hazards Model proposed by Cox (1972). In its continuous type version the model is specified as follows:

$$l(t;Z_i) = l_0(t) r_i(t) \quad (1)$$

where

$$r_i(t) = \exp(bZ_i(t))$$

is referred to as the risk score for the ith subject, β is a vector of regression parameters and $\lambda_0(t)$ is the baseline hazard function incorporating the ramdom element. The model does not include a constant term because it is incorporated in $\lambda_0(t)$. The expression $bZ_i(t)$ incorporates the influence of the covariates $Z_i(t)$ over the hazard rate. As we have seen in Section 3, the literature on intrafirm diffusion has suggested that these covariates are mainly related to firm-specific and innovation-specific characteristics. Their definition as time dependent covariates allows for the relaxation of the constancy assumed for some of the variables in theoretical and empirical models. Following Levin *et. al.* (1992), in this research the $Z_i(t)$ is also extended to include the influence of market and competitor factors.

5. DATA AND VARIABLES

As mentioned in the introduction, the data available for the empirical analysis refers to the diffusion of a product and a process innovation (Ingham and Thompson, 1993), the automated teller machine (ATM), through the distribution channels of a sample of Spanish Savings Banks during the period from 1981 to 1998[4]. ATMs are electro-mechanical devices that permit bank customers to make deposits and withdraw cash from their accounts and access other services such as balance enquiries, transfer of funds or acceptance of deposits. As a process innovation they substitute for labour, whereas as a product innovation they provide a service not restricted to opening hours.

The sample over which data is collected shares many common features with that described in Ingham and Thompson (1993) for the case of the UK. First, savings banks have been subject to tight regulation, which constrained important strategic variables such as the type of activities they have been able to perform or the price at which to sell products and services. Although deregulation in the last two decades is expected to have introduced a degree of heterogeneity, it provides us with an especially homogeneous

[4] This is the period for which data on the number of ATMs installed in the savings banks is available.

sample over which to investigate the effect of firm-specific variables on internal diffusion. Second, the elimination of restrictions has produced an increase of competition between savings banks as they have been allowed to perform new activities, open new branches in new locations or use price as a strategic variable. Furthermore, it has implied the recognition of commercial banks as close competitors and the interrelation between the two groups of financial intermediaries. This provides us with an excellent opportunity to analyse the influence of changes in market structure on the rate of internal diffusion.

To follow the first step of the procedure outlined in Section 4.1, data on the cumulative number of adoptions and on the relevant variables affecting the maximum number of adopters is needed. The key feature of the evolution of the market that justifies the use of a dynamic diffusion model is the increase in the number of branches. Prior to liberalisation, savings banks activities were geographically reduced in scope, with the largest operating within their autonomous regions and the smallest in one or two provinces. After the total lifting of entry regulation, the Spanish savings banks network substantially increased in size. Thus, from 1981 to 1998 the number of branches increases 80.6 %, from 10,484 to 19,594. For the case of the ATMs, these figures are 169 and 20,244, respectively. In this situation, given that, with a few exceptions, ATMs are in-branch devices, the assumption of a static market potential seems unrealistic. This increase in the number of branches has been closely followed by an increase in the amount of total deposits of more than 100% in constant terms.

Therefore, the hypothesis is that the function specifying the maximum number of adopters $\overline{N}(t)$ takes the following form:

$$\overline{N}(t) = f\left[B(t)\right] = K_1 + K_2 B(t)$$

where K_1 and K_2 are parametres and B(t) is the evolution of the total amount of deposits of the entity from adoption to 1998[5].

[5] The relevance of other factors (number of branches, increase in the number of branches, increase in the number of deposits) at explaining the evolution of the potential market was also tested. The evolution of the total amount of deposits was the variable that performed better.

The explanatory variables used in the analysis heavily draw on the ones suggested by the literature on intrafirm diffusion[6]. The profitability of the new technology (hypothesis 1) is the first factor to consider. As it has been mentioned before, as a process innovation ATMs substitute labour. Hannan and McDowell (1984) use the level of local market wage as the main proxy for this effect. In our case, firm labour expenditures are used under the hypothesis that differences among wages are found between entities and do not depend on the geographical area in which the operations of one savings bank take place (LABOU, labour expenditures normalised by assets). Then, LABOU is expected to have a positive influence over the intrafirm rate of diffusion. A second variable, branch size, is also introduced in the analysis to test hypothesis 1. We should expect the profitability of installing ATMs to depend directly on branch size BSIZE (number of employees per branch[7]) due to the presence of fixed cost. This variable indicates the degree in which a savings bank's branches exceed the minimum size necessary to justify the introduction of an ATM (Levin *et al.*, 1992). Therefore, we would expect to find a positive sign in the coefficient of this variable when the empirical analysis is performed.

The uncertainty surrounding the innovation (hypothesis 2) is the second factor to consider. Uncertainty is expected to be reduced the longer the period the innovation has been used by other firms. Later adopters may be able to learn from other firms' previous experiences with the new technology, which would increase the benefits of later adoption. TIME is a variable representing the time elapsed between the year of introduction of ATMs in Spain and the year of first adoption by the firm. According to our second hypothesis, this variable should show a positive estimated coefficient: the longer the delay to adopt the innovation the quicker the intrafirm diffusion process.

Firm size, SIZE, (hypothesis 3) is measured through total assets. Although other proxies for firm size (number of employees, total deposits,...) are available, they are not expected to show very different effects given the high correlation between them.

[6] A detailed description of the variables used in this research is presented in appendix 1.
[7] The variable deposits per branch was also calculated in order to proxy for branch size. Given the high correlation of this variable with SIZE (0.97), it was not used in the empirical analysis.

According to hypothesis 3, this variable should present a negative influence on the rate of intrafirm diffusion.

As we have mentioned before, Savings Banks are mutual institutions. This character prevents them from obtaining funds from the traditional sources (eg: the capital market) and limits the availability of financial resources to current profits and reserves. Therefore, the amount of total reserves (normalised by assets), LIQUI, is included in the analysis in order to proxy for liquidity effects. Similarly, the profitability of the entity, PROFI (return on assets), is also considered. Both variables have been suggested to have a positive effect on intrafirm diffusion (hypothesis 4), as an indicator of the ability of a firm to finance the investment and to take risks (Mansfield, 1963).

Finally, market structure (hypothesis 5) is captured through the calculation of a weighted Herfindahl index, CONC. It considers the concentration in the local markets in which Savings Banks operate. To calculate it, a province Herfindahl index was first developed using the number of branches as a proxy for market share. Then, the core market Herfindahl was worked out multiplying each single Herfindahl of the provinces in which the entity was operating in the corresponding year, by the relative importance of the province for the entity under observation (the number of branches was again used to measure the importance of the province for the entity). As we have seen, an inverse effect has been predicted. Therefore, a higher concentration should negatively influence the process of internal diffusion.

At the beginning of the period of analysis, the Savings Banks market consisted of 77 financial entities. This number of firms was reduced to 50 by the wave of mergers and acquisitions that took place at the beginning of the 1990s. In order to dispose of the maximum number of observations for the estimation of the dynamic market potential model we have considered that merged savings banks are a sole entity from the beginning. Therefore, the data that refers to an entity affected by any of these processes will be equal to the arithmetic sum of the corresponding data of the savings banks integrated in the new firm.

6. RESULTS

The results of the estimation of the rates of intrafirm diffusion from expression (4) are generally satisfactory[8]. On average, the model was able to explain more than 98% of the variance of the dependent variable. From the 50 coefficients estimated, 47 presented the expected sign. The value of the coefficients and the adjusted R squared of the estimated models are presented in appendix 2. As in Levin *et al*. (1992) no firm was omitted if the stage I model did not perform well.

Mansfield considers the time it takes a firm to complete the process of internal diffusion from 10% up to 90% of potential market. Table 2 presents these figures and average values for the independent variables just described. This information is complemented with the one presented in the appendix. As may be inferred from the survival function depicted in figure 1 (appendix 3), the number of years it takes a savings bank to complete the process of intrafirm diffusion ranges from 2 years for the quickest to more than 17 for the slowest. For the case of 11 entities the process is completed in a period of time no longer than 5 years. These figures are 24 for the entities that reach full internal diffusion in a period from 6 to 10 years and, finally, 12 entities take more that 10 years. A number of 37 entities out of a total of 47 whose potential market is available had finished the process of internal diffusion by 1998.

Some relevant conclusions may be extracted when this information is jointly examined with the averaged values for the independent variables[9]. In relation to the set of the first two hypotheses, the entities included in the first group seem to be the last to adopt the technology (hypothesis 2). This seems to confirm the idea that these entities decided to delay investment in order to take advantage of the reduction of uncertainty derived from other firms' experience with the new technology. However, no clear pattern is found when labour expenditures and branch size are considered (hypothesis 1).

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[8] As it has been explained, to apply the model data on the evolution of the amount of deposits from 1981 to 1998 is needed. This data is available for the whole period, with the only exception of year 1985. Given the absence of information for this year, the corresponding value was interpolated.

[9] A one factor ANOVA was performed in order to determine the significance of each variable at explaining the three groups identified. Just the lag of adoption of the innovation and the variable measuring the market structure were found to have a significant influence at the 99% level.

TABLE 2 . Years from 10% to 90% internal diffusion.

Years	Number of entities	LABOU	BSIZE	TIME	SIZE	PROFI	LIQUI	CONC
5 years or less	11	0.019	5.415	7.273	155429	1.326	0.054	0.100
From 6 to 10 years	24	0.020	5.768	5.500	227179	1.158	0.042	0.123
More than 10 years	12	0.020	5.113	5.083	422060	1.118	0.044	0.159
TOTAL	47	0.020	5.518	5.809	260143	1.187	0.046	0.127

Source: Own elaboration.

At first sight, Hypothesis 3 seems to be confirmed by the fact that the biggest entities are included in the group of those slowest at diffusing the innovation. However, these differences are not found to be statistically significant. The same happens when hypothesis 4 is examined, in spite of the fact that the LIQUI and PROFI variables take the higher values for those entities identified as the quickest. Finally, the Herfindahl Index (CONC) does have a significant and negative effect of concentration on internal diffusion, meaning that internal diffusion has proceeded slowly in more concentrated markets.

The 47 estimated b were used as the dependent variable in a second step in which the effect of the proposed variables on intrafirm diffusion was tested[10]. Table 3 presents the results of the estimation of several alternative specifications of the relationship between the b and the explanatory variables suggested by the literature on intrafirm diffusion. They are quite supportive. Overall, in all the cases the explanatory variables are able to explain more than 58% of the variance of the dependent variable, as measured by the ajusted R^2 statistic. This value is higher than the ones obtained in other empirical studies on intrafirm diffusion (Romeo, 1975; Globerman, 1976; Levin *et al*., 1992). As mentioned in Section 4 in all the cases the OLS estimates have been corrected for heteroskedasticity using White's method (White, 1980).

[10] Appendix 4 shows descriptive statistics on the explanatory variables used in this regression.

The first column of table 3 shows the estimation of a first model in which all the explanatory variables described in Section 4 have been included[11]. As has been mentioned, the statistics measuring the global goodness of fit are higher than the ones of other empirical analysis on intrafirm diffusion. From column 1 we may extract the following conclusions. Hypothesis 1 is partially confirmed. The ratio of labour expenditures to assets (LABOU) presents a positive and non-significant sign, indicating that cost saving issues are not relevant at explaining the rate of ATM diffusion. However, branch size (BSIZE) is shown to be determining factors when explaining internal diffusion. Those entities with a higher average branch size are the quickest at introducing ATMs in their branches. The reduction of the uncertainty surrounding the innovation does provide Savings Banks with an incentive to adopt more units of the new technology in less time. The longer the time lag between the first introduction of ATMs in the market and the adoption of the technology by the Savings Bank (TIME) the quicker the diffusion among all its branches. Therefore, later adopters seem to have learned from previous adopters' experiences, confirming hypothesis 2.

Firm size is shown to have a negative and significant effect on the speed of intrafirm diffusion, confirming hypothesis 3. Similarly to the findings of the literature on interfim diffusion (Buzzachi *et al*., 1995) the logarithmic specification of firm size performed better. Therefore, the rate of intrafirm diffusion is shown to decrease with the amount of total assets, but this is achieved at a decreasing pace. The opposite happens with the amount of available resources to finance the acquisition of ATMs. The LIQUI variable presents a positive sign, indicating that those savings banks with more "retained earnings" are the ones that present a higher rate of internal diffusion, confirming hypothesis 4. The profitability of the entity, however, is not shown to present any significant effect on the dependent variable[12]. Finally, the variable measuring market concentration (hypothesis 5) presents a negative and non-significant sign.

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[11] All the values of the explanatory variables are taken as in 1986, given that this is the first year in which we have information on them. The only exception is the variable PROFI, for which an average value, 1986-1988, was calculated.

[12] This result is consistent with the ones presented in Mansfield (1963) and Romeo (1975). In both cases, the profitability variable was found to be positive and no significantly related to the rate of intrafirm diffusion.

Table 3. Determining factors of the rate of intrafirm diffusion

	1	2	3
Independent Variables	**Estimated Coefficient**	**Estimated Coefficient**	**Estimated Coefficient**
CONSTANT	0,071	0,076	0,100**
	(0,154)	(1,513)	(2,349)
LABOU	0,690	0,317	
	(1,126)	(0,487)	
BSIZE	0,002*	0,003*	0,003**
	(1,772)	(1,838)	(2,306)
TIME	0,005***	0,005***	0,004**
	(2,709)	(2,776)	(2,292)
SIZE	-0,011***	-0,012***	-0,012***
	(-3,197)	(-3,156)	(-3,473)
PROFI	0,002	-3,1E-04	
	(0,409)	(-0,058)	
LIQUI	0,409**	0,375*	0,330*
	(2,098)	(1,959)	(1,910)
CONC	-0,007	0,285	
	(-0,216)	(1,276)	
CONC2		-1,001	
		(-1,275)	
Adj. R^2	0,5896	0,5890	0,6136
F-Statistic	10,44***	9,24***	19,27***
Num. obs.	47	47	47

Note: ***Statistical significance at 1% level. ** Statistical significance at 5% level. * Statistical significance at 10% level. T-ratios in parenthesis.

Given the non-significance of the variable capturing market concentration, column 2 attempts to further investigate its influence on the rate of intrafirm diffusion. As seen in Section 3, some authors point to the possibility that the relationship between market structure and innovative activity is quadratic. That is, this would imply that diffusion is maximised for intermediate levels of market concentration. Accordingly, column 2 presents new estimates in which this quadratic relationship has been specified. As shown, neither market concentration, nor its quadratic effect, presents a significant sign and global goodness of fit of the estimation is not significantly altered by the introduction of the quadratic effect.

Finally, the last column in table 3 presents estimates resulting from the elimination of the variables that were never significant in the two previous estimations. In this case, all the variables introduced in the analysis present the expected sign, all of them significant at the generally accepted levels and the global goodness of fit of the model is improved.

To further investigate the factors affecting the time elapsed from adoption to full internal diffusion, the Cox Proportional Hazards Model proposed in Section 4 was estimated[13]. The Efron (1977) approximation was used for handling ties. As in Mansfield (1963), the internal diffusion time was defined as the number of years from the acquisition of a number of ATMs equivalent from 10% to 90% of potential market. The analysis is performed using the same number of 47 entities that were used in the ordinary regression. The use of the time dimension of the data raises the number of available observations to 428. Note that the method allows us to relax the assumption that the explanatory variables remained constant throughout the diffusion period, used in the previous estimation[14]. The results of the estimates for the same three models presented in Table 3 are shown in Table 4. All three estimations are globally significant and present fairly stable coefficients. The estimated coefficients present some changes from the ones previously analysed.

TABLE 4 . Survival analysis of the determinants of intrafirm diffusion.

	1	2	3
Independent Variables	**Estimated Coefficient**	**Estimated Coefficient**	**Estimated Coefficient**
LABOU	-0.149***	-0.141***	-0.144***
	(-2.834)	(-2.801)	(-2.89)
BSIZE	0.377**	0.356**	0.355**
	(2.365)	(2.303)	(2.31)
TIME	0.436***	0.437***	0.454***
	(3.237)	(3.212)	(3.49)
SIZE	-0.725*	-0.626*	-0.619*
	(-1.788)	(-1.786)	(-1.79)
PROFI	-0.254		
	(-0.523)		
LIQUI	6.823	3.913	
	(0.639)	(0.422)	
CONC	-7.722*	-7.863*	-7.934*
	(-1.825)	(-1.832)	(-1.87)
Likelihood ratio	20.3***	20***	19.8***
Num. obs.	428	428	428

Note: *** Statistical significance at 1% level. ** Statistical significance at 5% level.
* Statistical significance at 10% level. T-ratios in parenthesis.

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13 Appendix 5 shows descriptive statistics for the variables used in the survival analysis.

14 This is, in fact, one of the criticisms of Stoneman (1983) to the model developed by Mansfield (1963). Mansfield assumes size, liquidity and the expected profitability of the innovation to remain constant over time.

The expected profitability of the innovation, as measured by the LABOU variable is shown to have a negative and highly significant effect on the conditional probability of having finished the internal diffusion process. These findings do not agree with the proposed hypothesis and the evidence brought forward by Hannan and McDowell (1984a,b) for the case of interfirm diffusion[15]. The effect of branch size is, again, positive and significant, confirming hypothesis 1. Therefore, as branch size increases, the rate of intrafirm diffusion shows a higher value, pointing out the importance of fixed cost at using ATMs (Levin *et al*., 1992).

The time lag of adoption of the innovation does have a negative effect (positive coefficient) on the time from adoption to full internal diffusion, as hypothesised. This, again, confirms the importance of uncertainty at explaining the speed of intrafirm diffusion. Firm size is shown to have a negative effect on the probability of having reached 90% diffusion[16]. Neither of the two variables measuring the availability of financial resources is, however, significant. Perhaps the more interesting findings of this second estimation are that, when the evolution of market structure during the period under analysis is taken into account, the influence of market concentration on the rate of intrafirm diffusion is shown to be negative and significant. This evidence is consistent with that presented in Levin *et al*. (1992) and clearly rejects the link between market structure and innovation activity suggested by the Schumpeterian hypothesis, providing us with interesting conclusions regarding the transformations that have affected the market following liberalisation. Intrafirm diffusion seems to have been favoured by the changes that have affected the market and reduced the concentration levels, as measured by the Herfindahl Index. In this sense, perhaps the most beneficial effect has to be associated to the entry processes derived from the elimination of branching restrictions.

Table 5 presents the result of exponentiation of the values of the coefficients of the variables that were significant in the survival analysis.

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[15] In Maudos (1994) the intensity of use of the ATMs in the Spanish savings banks is studied. Contrary to hypotheses, he also obtains a negative (although significant at the 86% level) coefficient for the LABOU variable measured as labour expenditures per employee.

TABLE 5 . Change in the hazard of a one-standard deviation change in the covariates.

Independent Variables	Exponentiated Coefficient	Change in the hazard
LABOU	0.865	0.522
BSIZE	1.425	1.638
TIME	1.574	1.960
SIZE	0.538	0.622
CONC	3.58E-04	0.689

The interpretation of the coefficients is analogous to the classical regression. For example, for the case of the variable TIME, an additional year of delay in the adoption of ATMs increases the hazard of having reached full internal diffusion by 1.574. In the same way, an increase in a standard typical deviation in this variable implies that the conditional probability of having completed 90% of the potential market almost doubles (1.960). In the case of the concentration variable, this conditional probability is multiplied by 0.689.

7. CONCLUSIONS

This paper investigates the factors explaining the intrafirm speed of diffusion of a new technology, the ATM, in the Spanish savings banks through the use of a dynamic diffusion model. The analysis of this dimension of the diffusion process has been largely neglected by both the theoretical and the empirical literature on technological progress. The relevance of covering this gap in the literature is explained by two important factors. First, new technology is frequently divisible and provided in a large number of small units, rendering the initial adoption as only a first step in the wider diffusion process. This is, in fact, the case of the ATMs. As we have seen, the end of the observation window time of our empirical analysis, the number of units introduced by the savings banks was well over 21,000. Second, its importance increases due to the fact

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[16] Given the high correlation between the natural logarithm of firm size and TIME (0.52) this

that a great deal of the internal diffusion process takes place among a population of big firms. This is, again, the case of the Spanish savings banks in which intrafirm diffusion takes place among a sample of 50 entities, with the 3 largest accounting for more than 44% of the installed machines (9,628 units).

As pointed out by Mansfield (1963), the analysis performed confirms that interfirm and intrafirm diffusion processes share common features. However, there are also some distinguishing characteristics. Following previous research, innovation, firm and market specific factors have been included in the analysis. Special emphasis has been placed on the hypothesis associated to the effect of firm size and market structure.

The results are satisfactory in terms of the support received by the hypothesis proposed. The application of the regression and survival methods over the data suggests that the influence of firm size and market structure on the rate of intrafirm diffusion are clearly not Schumpeterian. Firm size is shown to have a negative effect on the rate of intrafirm diffusion. These findings agree with previous research that indicates that smaller firms are quicker in decision processes and need a lower amount of total investment to fully adopt the innovation. However, it points in the opposite direction to interfirm studies, in which the influence is found to be positive. In the same way, the relation between market concentration and intrafirm diffusion has been found to be negative. Internal diffusion seems to be quicker the lower the level of concentration in the market, confirming the hypothesis proposed by Mansfield. This result adds new evidence on the conflicting effects of market structure on innovation and diffusion presented in the literature. It also suggests that entry and the subsequent increase in rivalry that has taken place in the geographical markets in which the savings banks operate have been beneficial from the point of view of dynamic efficiency.

The testing of the hypothesis concerning the expected profitability of the innovation offers conflicting results. Whereas it shows that higher labour expenditures do not have the predicted effect on the rate of diffusion, it also highlights the importance of fixed costs and minimum branch size over intrafirm diffusion. Savings bank profitability has been shown not to have any effect over the rate of intrafirm

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transformation was not used in this case.

diffusion. Although this contradicts the hypothesis developed, it is in agreement with other studies with the same objectives (Mansfield, 1963; Romeo, 1975). Finally, contrarily to the literature on interfirm diffusion, an attempt has been made to distinguish between the effects of size and liquidity with the introduction of a variable measuring the latter. The results show that liquidity does have a positive and significant effect on the rate of internal diffusion, as expected.

The last factor that explains the rate at which savings banks have proceeded with the diffusion process is the time lag of adoption (time from first adoption in the industry). As pointed out in the main text, the later the adoption time the quicker the diffusion process. Thus, later adopters may have benefited from the experience accumulated on the new technology by other entities. As argued by Pindyck (1991), the option of waiting may have a great value if there is important information to arrive and strategic factors do not compel the savings banks to quickly go forward in the diffusion process. The result highlights the role of the uncertainty associated with the innovation when explaining investment in new technologies.

The empirical analysis has been performed making use of survival or duration models. These models take the time to an event as the dependent variable in the analysis. Although they had been applied to the analysis of interfirm diffusion, no attempt had been made to use this type of models in the study of the speed at which innovations diffuse in the firm.

Some limitations and extensions derive from our research. In relation to the first, the main ones are related to the assumptions underlying the fundamental diffusion model. In our context, perhaps the most relevant is the one that assumes that the technology does not change during the diffusion process and that it is independent of other innovations. Given the long time period elapsed from first introduction of ATMs and the speed at which information technologies have evolved and have been applied to banking in the recent years, this may be unrealistic.

In relation to the second, given the developments in the Spanish banking sector, the analysis could be extended in order to disentangle the effects of strategic factors over the rates of intrafirm diffusion. These effects have been, in fact, already considered in the interfirm diffusion literature. Thus, Hannan and McDowell (1986) and Sharma (1993) test the influence of rival precedence in the adoption of ATMs in the US banking market. As they point out, the theory has yielded ambiguous predictions on the impact of this factor over the probability of adoption. Whereas rival precedence may reduce uncertainty about the profitability of the innovation it also reduces this profitability due to the provision of a higher quality of service. The influence of strategic factors such as the ones studied in these two papers has not been undertaken in the intrafirm dimension and could constitute a next step in future research.

APPENDIX 1. DEFINITION OF VARIABLES.

TABLE 6. HYPOTHESES AND MEASUREMENT

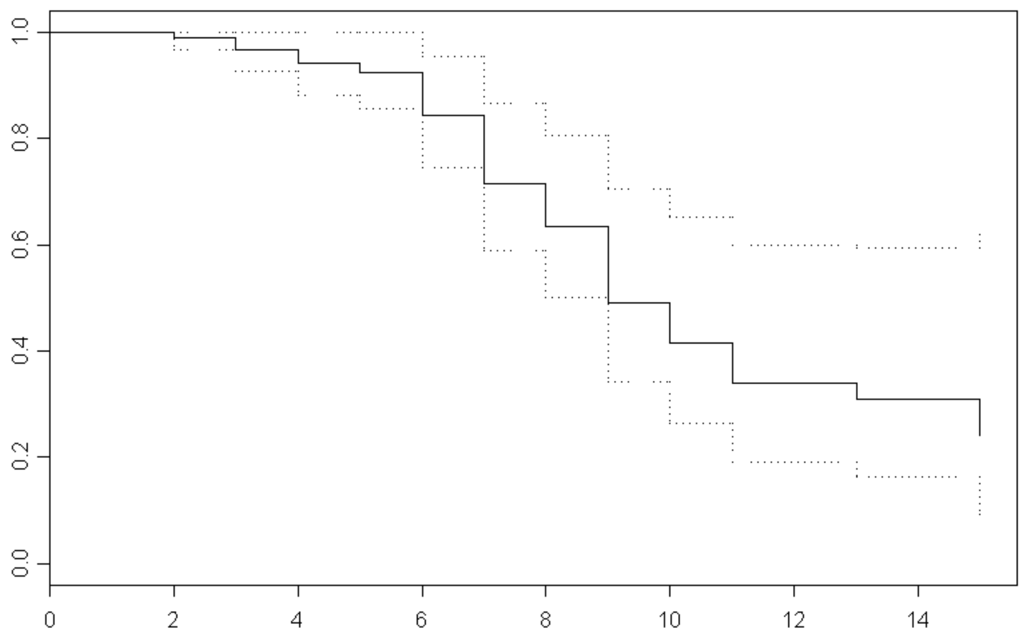
HYPOTHESIS	VARIABLES
H1: Expected profitability	**LABOU**: total labour expenditures divided by total assets. Data on this variable is available from 1986 to 1998.
	BSIZE: total number of employees divided by the number of branches. Data on this variable is available for 1986.
H2: Uncertainty	**TIME**: time elapsed between the adoption of automated teller machines by the first firm in the market and the firm under analysis.
H3: Size	**SIZE**: Total assets. Data on this variable is available from 1986 to 1998.
H4: Liquidity	**LIQUI**: equity divided by total assets. Equity includes capital, rotation fund, reserves, subordinated financing and retained earnings. Data on this variable is available from 1986 to 1998.
	PROFI: average profitability measured as net profit divided by total assets. Data on this variable is available from 1986 to 1998.
H5: Market structure	**CONC**: Overall Herfindahl Index in the provinces in which the entity is operating. This index was calculated as follows. A province Herfindahl was first developed using the number of branches as a proxy for market share. Then, the core market Herfindahl was worked out multiplying each single Herfindahl of the provinces in which the entity was operating in the corresponding year, by the relative importance of the province for the entity under observation (the number of branches was again used to measure the importance of the province for the entity). Data on this variable is available from 1986 to 1998 and has been calculated taking into account both types of intermediaries, banks and savings banks.

APPENDIX 2. RATES OF INTRAFIRM DIFFUSION.

	Coefficient	Adj. R-Squared
Asturias	-2.90E-04	0.99
Avila	-1.22E-02	0.98
Badajoz	-2.51E-03	0.99
Baleares	-3.87E-03	0.99
Bancaja	-1.40E-03	0.98
BBK	-8.67E-04	0.99
Burgos C.C.O .	-4.57E-03	0.99
Burgos Munic.	-1.26E-02	0.99
Caja España	-7.06E-04	0.99
Canarias Gral.	-2.00E-03	0.99
Canarias Insular	-4.23E-03	0.98
Carlet	-5.49E-02	0.95
Castilla	-3.06E-03	0.99
Cataluña	-1.25E-03	0.99
Cordoba	-1.51E-03	0.99
Extremadura	-7.84E-03	0.99
San Fernando	-4.32E-03	0.99
Galicia	1.41E-03	0.99
Gerona	-4.80E-03	0.99
Granada Gral.	-1.28E-03	0.99
Guadalajara	-3.33E-02	0.99
Guipúzcoa	-2.09E-03	0.99
Huelva-Sevilla	-4.80E-03	0.99
Ibercaja	-5.92E-04	0.99
Inmaculada	-2.42E-03	0.99
Jaén	-1.11E-01	0.91
La Caixa	-4.01E-05	0.97
Laietana	-1.89E-02	0.98
Madrid	-2.63E-04	0.97
Manlleu	-8.44E-03	0.98
Manresa	-6.97E-03	0.98
Mediterráneo	-1.28E-03	0.97
Murcia	-1.15E-02	0.98
Navarra	-4.44E-04	0.99
Ontinyent	-4.29E-02	0.95
Orense	8.41E-03	0.95
Pamplona	-9.84E-03	0.97
Penedés	-3.80E-03	0.99
Pollensa	-1.53E-01	0.94
Pontevedra	-5.96E-03	0.97
Rioja	9.47E-03	0.98
Sabadell	-6.37E-03	0.98
Duero	-5.69E-03	0.99
Santander	-6.26E-03	0.97
Segovia	-1.63E-02	0.94
Tarragona	-3.85E-03	0.97
Tarrasa	-5.09E-03	0.98
Unicaja	-3.30E-04	0.99
Vigo	-7.07E-03	0.95
Vital	-2.64E-03	0.89

APPENDIX 3. SURVIVAL ANALYSIS OF INTRAFIRM DIFFUSION

Figure 1. Estimated hazard function



APPENDIX 4. REGRESSION ANALYSIS OF INTRAFIRM DIFFUSION

TABLE 7 . DESCRIPTIVE STATISTICS

	LAB	BSIZE	TIME	SIZE	PROFI	LIQ	CONC
Min:	0.011	2.453	4.000	3686	0.031	0.016	0.062
Mean:	0.020	5.518	5.809	260143	1.187	0.046	0.127
Max:	0.028	8.991	10.000	2604568	2.076	0.095	0.268
Total N:	47	47	47	47	47	47	47
Std Dev. :	0.004	1.388	1.715	422133	0.459	0.015	0.048

TABLE 8. CORRELATION BETWEEN THE VARIABLES

	LAB	BSIZE	TIME	SIZE	PROFI	LIQ	CONC
LAB	1.000						
BSIZE	0.195	1.000					
TIME	-0.027	-0.246	1.000				
SIZE	-0.190	0.247	-0.267	1.000			
PROFI	-0.392	-0.004	0.162	-0.395	1.000		
LIQ	-0.441	0.039	0.253	0.113	0.364	1.000	
CONC	0.046	-0.042	-0.218	-0.106	0.171	-0.022	1.000

APPENDIX 5. SURVIVAL ANALYSIS OF INTRAFIRM DIFFUSION.

TABLE 9 . Descriptive statistics.

	LAB	BSIZE	TIME	SIZE	PROFI	LIQUI	CONC
Min:	0.527	2.453	4.000	0.004	0.031	0.015	0.062
Mean:	18.697	5.460	5.530	0.398	1.164	0.064	0.141
Max:	30.051	8.991	10.000	5.331	2.076	0.145	0.347
Total N:	428	428	428	428	428	428	428
Std Dev.:	4.516	1.390	1.483	0.768	0.457	0.026	0.047

TABLE 10. Correlations between the variables

	LAB	BSIZE	TIME	SIZE	PROFI	LIQUI	CONC
LAB	1.000						
BSIZE	0.247	1.000					
TIME	0.229	-0.228	1.000				
SIZE	-0.301	0.202	-0.175	1.000			
PROFI	-0.259	-0.037	0.053	-0.393	1.000		
LIQUI	-0.301	-0.095	0.048	0.141	0.217	1.000	
CONC	-0.168	-0.179	-0.142	-0.024	0.116	0.121	1.000

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