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AN ANALYSIS OF THE RETURNS TO EARLY ADOPTION OF EXTERNALLY SOURCED TECHNOLOGIES

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Abstract

This paper analyses returns to the early adoption of externally sourced technologies. We argue that early adopters obtain higher returns than subsequent adopters because they benefit from two kinds of advantages: advantages in order of adoption, which correspond to conventional first mover advantages (FMAs), and advantages in time of adoption, which stem from the temporal profile of the intrafirm diffusion process. We discuss a conceptual model that identifies different components of the advantage that accrues to early adopters. Then, we describe how these components are conceptually different, have different links with previous research on FMAs, and vary in their expected sustainability. We conclude that, to appropriately detect the presence of FMAs, it is necessary to pay attention to the process by which new technologies are incorporated into productive activities and the differences in this process between early adopters, early followers and late adopters.

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Key words:

First mover advantages, early adopter, externally sourced technologies, order of adoption, time of adoption.

1. INTRODUCTION

First mover advantages (FMAs) have been a central research topic in strategic management since the seminal paper by Lieberman and Montgomery (1988). FMAs refer to the ability of pioneering firms to earn positive economic rents in excess to followers. Firms become pioneers by being the first to enter into a market, introduce a product or adopt a new process (Kerin et al., 1992). There is a vast amount of research that analyzes the existence, height and sustainability of FMAs in the case of new product introductions or entry into new markets. The evidence tends to offer support for the existence of FMAs (Vanderwerf and Mahon, 1997), although their sustainability may depend on contextual factors (Suárez and Lanzolla, 2007) and on the strategies implemented by pioneers and followers (Lieberman and Montgomery, 1998).

While pioneers can appear in the case of new markets, new products and new processes or technologies, previous empirical research on the existence of FMAs seems to have paid much more attention to the two first cases. Nevertheless, pioneers may arise in other situations, such as the adoption of new technologies. In this research we focus on a situation that is becoming increasingly frequent: the adoption of externally sourced technologies[1]. Although this may seem a very different context, the analysis of FMAs in the adoption of externally sourced technologies shows certain distinctive factors that can provide some relevant insights to the theory. In particular, the literature argues that pioneers benefit from three isolating mechanisms: technological leadership, preemption of scarce resources and switching costs. These mechanisms may be employed to analyze the advantages accruing to pioneers in the adoption of new technologies. However, the special characteristics of externally sourced

[1] Interestingly, in technology diffusion research order of adoption has been a main factor explaining adoption decisions based on profitability expectations (Fudenberg and Tirole, 1985; Karshenas and Stoneman, 1993; Reinganum, 1981). Apparently, there is much more research *assuming* the existence of order effects on new technologies than research *testing* for their existence.

technologies in terms of these three mechanisms provide an interesting context for the research on both the existence and sustainability of FMAs.

We propose that early adopters of externally sourced technologies enjoy two different kinds of advantages: advantages in the order of adoption and advantages in the time of adoption. These two components are conceptually different, and their delimitation is central for the correct identification of FMA. To distinguish between them, we pay special attention to the process by which technologies are progressively incorporated into the activities of adopters, and how this process is related to advantages in the time of adoption. Therefore, the study of the process of internal diffusion of the technology allows us to distinguish *pure* FMAs from other advantages that also accrue to the early adopter.

Our approach takes the framework proposed by Lieberman and Montgomery (1988) as the starting point. Lieberman and Montgomery (1988) argue that the sources of FMAs can be classified in three groups: technological leadership, preemption of scarce assets and buyer choice under uncertainty. The existence and duration of FMAs depend on the presence and sustainability of these sources. Therefore, advantages in the order of adoption depend on these factors. Advantages in the time of adoption, in contrast, arise from comparison of the time pattern by which new technologies are incorporated into the productive activities of early adopters and followers. The model we propose, by properly identifying these different components of returns to early adoption and their own temporal profiles, allows for a robust analysis of the sustainability of FMA in the context of externally sourced technologies.

We apply our model to a sample that describes the diffusion of the Automated Teller Machine (ATM) among the Spanish savings banks between 1988 and 2004. This time horizon begins with the year in which every firm had already adopted the ATM, and captures most of its evolution until it became an essential technology in the savings bank sector. Our data allows us to identify both the adoption date and the amount of technology that is incorporated into the activities of adopters. Our empirical analysis illustrates how early adoption advantages can be decomposed into different elements with different interpretations.

This paper contributes to the literature on FMAs in two ways. First, externally sourced technologies are a rather conservative context for the analysis of FMAs. The intrinsic characteristics of technological innovations purchased from specialized suppliers render FMAs difficult to be obtained, and almost impossible to be sustained. Finding evidence of FMAs in this research setting would imply that FMAs should be present in other instances of new technology adoption and, more generally, it would mean that FMAs are more frequent than it may be a priori expected. Second, by identifying the two components of early mover advantages, one transitory and highly dependent on time, and another more permanent and dependent on order of adoption, we contribute to the understanding of the type of advantages that accrue to early movers.

The rest of the paper is structured as follows: Section 2 offers an overview of the sources of FMA and puts them in the context of externally sourced technologies. Section 3 presents the operating model with which we analyze the returns to early adoption. In section 4 we describe the research setting for the empirical analysis. Section 5 explores advantages in time of adoption and advantages in order of adoption, and uses them to quantify the components of returns to early adoption. Section 6 closes the article discussing our findings and offering the main conclusions of this research.

2. EXTERNALLY SOURCED TECHNOLOGIES AND FMAs

The early adoption of externally sourced technologies is a theoretically appealing context for the analysis of FMAs. A first reason is that, among the different ways by which a firm can become a pioneer, the adoption of new processes or technologies has received less attention. A second reason is that externally sourced technologies offer a weak regime of appropriability (Teece, 1986). The returns to the adoption of these technologies are likely to dissipate quickly, as the number of firms using the technology increases (Carr, 2003; Teece, 1986). Therefore, this article offers a conservative test of FMAs. Third, the context requires a specific way to analyze FMAs. Process technologies are usually adopted following a piecemeal approach, resulting on an *intrafirm diffusion process* (Battisti and Stoneman, 2003). As a consequence, levels of adoption are highly dependent on time, and the technology is incorporated into firms following a predictable pattern. Both, the time dependent nature of intrafirm diffusion and the consideration of its typical pattern are important for the analysis that we perform in this article.

In this section we first briefly review the sources of FMAs. Then, we particularize to the context of externally sourced technologies and discuss on the possibility of obtaining FMAs. Finally, we describe the intrafirm diffusion process and its implications for both the interpretation and analysis of FMAs.

2.1 First mover advantages

According to Lieberman and Montgomery (1988) there are three sources of FMAs: technological leadership, preemption of scarce assets, and switching costs and buyer choice under uncertainty. *Technological leadership* refers to advantages stemming from the superior position of the pioneer in the learning curve and from proprietary technologies. First movers accumulate experience and learning about the new product, market or process before other firms imitate. This superior position can be easily translated into competitive advantages that allow the first mover to bear lower costs or command a higher price. Also, when technologies depend on R&D efforts, pioneers enjoy an early head start in R&D or patent races that may result into proprietary technologies and, consequently, a competitive advantage.

Preemption of scarce assets refers to the capability of the pioneer to acquire assets in better conditions than followers. Pioneers can hoard scarce strategic assets, preventing followers from obtaining them, or can acquire them at lower prices than those that will prevail once followers enter the market and the demand for these assets increases. Assets that can be preempted can be as diverse as input factors, locations in geographical and product characteristics space, or even demand, by aggressively investing in productive capacity and equipment. Finally, s*witching costs and buyer choice under uncertainty* benefit first movers when customers develop a preference for the firm with which they are already involved in exchanges. Customers may be reluctant to switch to another supplier when it would result on costs of any form, such as high initial transaction costs (e.g., coordination of supply chains), loss of specific learning to the supplier, or costs from contractual conditions (e.g., incentives programs or clauses against termination). Customers may also be reluctant to switch when it is difficult to ascertain the quality of the offering of the new entrant, especially when the pioneer already satisfies their expectations.

2.2 Externally sourced process technologies and FMA

The dominant perspective in strategic management argues that any asset than can be acquired in a highly developed factor market cannot provide a sustainable competitive advantage (Barney, 1986; Peteraf, 1993). In the case of technologies, this argument leads to conclude that technologies acquired *off-the-shelf* cannot provide sustainable competitive advantages by themselves because they cannot generate superior positions (Carr, 2003). However, FMAs theory argues that early adopters can benefit from certain isolating mechanisms that provide them with an advantage over subsequent adopters. In this article we distinguish two kinds of advantages; advantages in order of adoption and advantages in time of adoption. As we shall show below, this difference is critical for the correct understanding of FMAs and returns to early adoption in this context.

By externally sourced technologies we mean technological innovations that are developed by specialized suppliers and made available as commodities. These technologies can be acquired by firms of any size because they tend to be divisible, they are affordable due to their extensive distribution, and they do not require complex innovative capabilities because suppliers act as facilitators, offering technical support. Information Technologies are an archetypical case of this kind of technologies (Carr, 2003; Mata, Fuerst and Barney, 1995). We exclude other forms of interaction in the market for technologies, such as R&D contracting, or technologies made to order in which the adopter acquires exclusive access.

The attributes of externally sourced technologies severely reduce the capability of adopters to obtain FMAs. *Technological leadership* benefits accrue to the supplier of the technology. The supplier retains patents and core property rights, and obtains most of the learning-based benefits. As suppliers make the technology available to any potential adopter and usually offer technical support, it is difficult for early adopters to achieve technological leadership. Therefore, early adopters are unlikely to enjoy technological leadership advantages. However there is some room for the *preemption of scarce assets*. Early adopters cannot preempt product characteristics space because, if the technology had a relevant impact on product attributes, those may be easily imitated. However, early adopters can still preempt critical input factors (specialized human resources, complementary services), or intensively invest on plant and capacity.

Adopters can also benefit from *switching costs and buyer choice under uncertainty*. Advantages based on customer fidelity or switching costs are associated to entry into markets or the launch of new products. However, for process technologies that span the boundaries of the organization (e.g., require some form of integration with suppliers or customers) there is still room for switching costs. Nevertheless, the persistence of advantages based on switching costs, the so-called *Create-Capture-Keep* paradigm, has been widely criticized (Mata et al., 1995; Powell and Dent-Micallef, 1997). Therefore, early adopters shall obtain limited gains from this kind of advantages.

From the discussion above it can be concluded that in the case of eternally sourced technologies FMAs may still arise, but they may well be small and fragile.

2.3 Advantages in order of adoption and advantages in time of adoption

Despite the fragility of technological competitive advantages in regimes of weak appropriability, previous research shows that under some conditions the adoption of externally sourced technologies can be related to improvements on operational (Devaraj and Kohli, 2003; Fuentelsaz, Gómez and Palomas, 2009; Hitt and Brynjolfsson, 1996) and financial performance (Fuentelsaz, Gómez and Palomas, 2012; Powell and Dent-Micallef, 1997). We argue that to understand whether superior performance is due to the existence of FMAs or it has other origins we have to distinguish between two components: *advantages in order of adoption*, which are pure FMAs, and *advantages in time of adoption*, that are related to the intrafirm diffusion process.

Advantages in order of adoption accrue to firms that occupy low positions in the order of adoption of a given technology. These advantages correspond to FMAs in a strict sense because they accrue to the few first adopters of the technology. Subsequent adopters may still have access to some of them, but their size should decrease in the number of previous adopters (e.g., some complementary assets may still be available for early imitators, but in worse conditions than the very first adopters). Order advantages are produced and sustained by the mechanisms reviewed above. Although our contention is that advantages in the order of adoption should be present, we above describe how they are especially difficult to be obtained in the case of externally sourced technologies.

Advantages in time of adoption stem from differences in the timing in the incorporation of the technology to productive activities. These advantages are not exclusive to the early adopters. Any adopter enjoys these advantages in relation to subsequent adopters, and proportionally to the difference between their adoption dates.

In the context of new technologies, these advantages are related to the intrafirm diffusion process. A stylized fact in technology diffusion research is that technologies are seldom immediately incorporated into productive activities. Instead, their incorporation extends over time in a process that is called *intrafirm diffusion* (Battisti and Stoneman, 2003; Mansfield, 1963). Intrafirm diffusion refers to the process by which units of technology are accumulated over time, substituting for the old technology or process. Technologies are first implemented in selected organizational subunits (e.g., departments, factories, subsidiaries, offices), and later progressively spread over the organization. As a result, the level of adoption varies over time. Intrafirm diffusion processes have been observed for technologies as diverse as the diesel locomotive (Mansfield, 1963), optical scanners (Levin, Levin and Meisel, 1992), electronic mail systems (Astebro, 1995), telephone electronic switches (Cool et al., 1997), automated teller machines (Fuentelsaz, Gómez and Polo, 2003), flexible production systems (Battisti and Stoneman, 2005) and e-business activities (Battisti, Canepa and Stoneman, 2009).

There are many reasons for this progressive adoption. First, the acquisition and implantation of a process technology is costly. Among others, there are costs associated to the purchase of equipment, initial installation, training programs or disruptions on activities (Bunduchi, Weisshaar and Smart, 2011). Many of these costs soar when many organizational subunits are simultaneous affected. As a result, firms normally follow a piece-meal approach to adoption. Second, financial resources are critical for the acquisition of new technologies (Fuentelsaz et al., 2003; Gómez and Vargas, 2009). Facing many alternative uses for their limited financial resources, adopters tend to acquire units of technology progressively (Mansfield, 1963). Third, adopters have to learn new routines and adapt their internal structures and processes (Atewell, 1992; Stoneman, 1981). These changes require time, and force adopters to incorporate the technology progressively.

The existence of an intrafirm diffusion process opens an opportunity to early adopters. Early adopters enjoy a head start in the accumulation of units of technology because of their advantage in time of adoption. Intrafirm diffusion is heavily time-dependent (Fuentelsaz et al., 2003; Mansfield, 1963). Early adopters benefit from a technology gap in the form of higher levels of adoption because their process of accumulation of technological assets has been advancing for longer. Therefore, the temporal structure of the intrafirm diffusion process generates the opportunity for advantages in time of adoption. Intrafirm diffusion follows a sigmoidal shape (Fuentelsaz et al., 2003; Mansfield, 1963). At the beginning of the process, intrafirm diffusion advances slowly (see figure 1). After a point, intrafirm diffusion takes off, increasing at a higher rate until it approaches the maximum level, when it slows again. Therefore firms that adopt earlier show superior adoption levels. However, the technological gap reduces over time. For instance, in figure 1, a one-year lead time results on a greater gap at t_1 (t_1, t_{1+1}) than at t_2 (t_2, t_{2+1}). Consequently, any advantage based on this technological gap will be transitory by its own nature.

-- Insert Figure 1 about here –

In summary, early adoption of externally sourced technologies can provide advantages of two kinds. First, early adopters can benefit from their advantage in order of adoption in the form of pure FMAs. Second, early adopters can also benefit from advantages in time of adoption in the form of superior levels of adoption. This distinction is crucial for the analysis of FMAs and their sustainability. First, unless advantages in time of adoption are distinguished from advantages in order of adoption (i.e., FMAs) the latter may be inflated[2]. For example, there may be no FMAs, and still observe that early adopters enjoy superior returns from the technology as a result of their advantage in time of adoption. Second, as advantages in time of adoption are transitory, if they are not separated from FMA, their reduction may be wrongly interpreted as FMA erosion. For example, we may observe a reduction on returns to early adoption over time even in the case of persistent FMA.

[2] In this article we stick to a perspective in which FMAs do not include lead-time, as this advantage accrues to any firm in comparison to subsequent movers, and not strictly to the pioneer (e.g. Brown and Lattin, 1994; Huff and Robinson, 1994; Suarez and Lanzolla, 2007).

3. DECOMPOSING THE RETURNS TO EARLY ADOPTION

Not every advantage that accrues to early adopters can be classified as pure FMAs. By definition, some time elapses between adoption by the early mover and imitation by followers. Therefore, early adopters enjoy both advantages in order of adoption and advantages in time of adoption. Advantages in time of adoption, such as lead-time, are not considered as pure FMAs, as they are not exclusive of first movers, but accrue to any firm in relation to later movers. Formal definitions of FMAs acknowledge this distinction. For example, Suarez and Lanzolla (2007:382) define FMA as "*the performance gain that a firm attains from being first to market in a new product category, once other effects (namely, firm resources, lead time) have been controlled for*"[3]. Kerin et al., (1992:42), citing Porter (1983), define FMAs as "*factors that enable the firm to translate a technology gap into other competitive advantages that persist even after the gap is closed*". Consequently, a robust analysis of FMAs should explicitly distinguish between order effects and advantages in time of adoption.

Ignoring such a distinction may be misleading. Considering that any abnormal return obtained by the early adopter belongs to the category of pure FMAs mistakenly conflates them and other advantages that accrue to early movers but stem from "fast(er) moverness" rather than from "first moverness". This distinction is especially important in the case of externally sourced, divisible technologies, because returns to early adoption have a component based on the accumulation of technological assets that accrues to any firm in relation to subsequent adopters, and that is potentially transitory. An analysis of the sustainability of FMAs that does not control for this transitory component may offer inaccurate conclusions, incorrectly attributing all the returns to the order of adoption. In this section we distinguish between the returns associated to pure FMAs and those linked to differences in time of adoption.

[3] While Suarez and Lanzolla (2007) refer to FMAs in new products, they still stress the importance of controlling for factors that accrue to pioneers but are not strictly FMAs.

Figure 2 shows a graphical representation of our conceptual model. Over the Y axis we represent the value captured from each unit of the level of adoption (measured as unit of technology per unit of activity). FMAs increase the value adopters obtain from each unit of the technology. The position along this axis represents order effects that correspond to FMAs; early adopters will have a higher value per adoption unit than late adopters because of their advantage in order of adoption. In the X axis we represent the level of adoption. This second dimension is linked to the time elapsed from adoption, according to the time structure identified for intrafirm diffusion (Battisti and Stoneman, 2003; Mansfield, 1963). Firms may obtain advantages in the level of adoption as a result of having begun the intrafirm diffusion process earlier than subsequent adopters. Therefore, early movers have higher levels of adoption because of their advantage in time of adoption. The model reflects the two sources of advantages of early adopters keeping them as different elements.

-- Insert Figure 2 about here –

In the model, the profitability that a firm obtains from the technology is the product of the value captured from each adoption level unit (Y axis) multiplied by the level of adoption (X axis). An early adopter (point A) obtains returns equal to the combination of areas I, II, III and IV (β_{EA} x LA_{EA}). Assuming the presence of FMAs and a standard intrafirm diffusion process, point B represents a late adopter (lower returns from each unit and lower level of adoption). Returns to late adoption are equal to area I (i.e., β_{LA} x AL_{LA}). The advantage that the early adopter enjoys is the gain in excess to the late adopter. Therefore, the advantage corresponds to areas II, III and IV. Importantly, these areas represent different components of early adopter advantages. The interest in these components is justified by the fact that each of them has a different interpretation and a different (expected) durability.

Area II represents the excess returns that accrue to firm A that are obtained from pure FMAs, i.e., from advantages that persist when the technological gap is closed. In other words, returns stemming from pure FMAs are interpreted as the differential in gains that the early adopter would still obtain if its level of adoption was the same as the level of adoption of the late adopter. The area, calculated as (β_{EA} - β_{LA}) x AL_{LA}, represents the returns from pure FMAs. The difference β_{EA} - β_{LA} represents the advantage that the early adopter enjoys for each unit of adoption. It is important to note that when we acknowledge the divisibility of the technology, the returns that stem from FMAs depend on adoption levels, and grow with the intrafirm diffusion process. Even when the size of the FMAs is constant, gains stemming from them grow over time as the intrafirm diffusion process develops. Area II is the component that we define as stable, because it is not dependent on adoption level advantages, which are transitory due to the temporal profile of the intrafirm diffusion process.

Areas III and IV are also early adopter advantages accruing to firm A. However, they do not fit into a strict definition of FMAs because *they depend on the technological gap generated by the differential on the level of adoption*. Area III represents excess gains stemming from a superior level of adoption. It is a component of the returns to early adoption that is available to any firm in relation to subsequent adopters. It is calculated as the product of the differential on adoption level and the profitability per unit of adoption of the late adopter, β_{LA} x (LA_{EA} – LA_{LA}). Area IV represents the excess returns that firm A obtains from the combination of a higher value on each unit of adoption (advantage in order) and a higher level of adoption (advantage in time). It is calculated as (β_{EA} - β_{LA}) x (LA_{EA} – LA_{LA}).

In summary, according to this model, it is possible to identify three different components of returns to early adoption, and empirically quantify each of them. More importantly, the model also allows us to empirically distinguish pure FMAs from other order of adoption advantages whose omission would confound the empirical analysis. In the remainder of the article we exploit this conceptual model to analyze FMAs in the context of externally sourced technologies. Specifically, the model will be used to explore both the presence and sustainability of the different components of FMAs.

4. RESEARCH SETTING

We illustrate the model on a dataset that describes the diffusion of the Automated Teller Machine (ATM) in the Spanish savings banks sector. Our research window begins in 1988, the year in which every savings bank had already adopted the ATM, and finishes in 2004, when the technology had become a normal component of the branch.

The ATM is an IT device that connects the user with the entity in which he/she holds its checking account. The user can carry out many basic routines through a terminal, such as cash withdrawal or account balance inquiries. The ATM improves the process by which routine services are delivered to banking customers, increasing the value provided by the bank. First, ATMs can be accessed 24 hours a day, allowing customers to receive some basic services at any time. Second, the technology complements the activities of human tellers, enhancing the productivity of the branch. Third, the ATM significantly reduces the cost per operation. The cost of a transaction performed from an ATM ranges between 28% and 40% of the cost of performing the same transaction from a traditional branch (European Central Bank, 1999). Therefore, this technology provides remarkable operational improvements.

The ATM is commercialized by international specialized providers, which make the technology available to any prospective adopter at a lower cost than the development and production by prospective adopters. In the period analyzed the technology presents relatively little variation. While there have been many technical improvements, the most used services (i.e., cash withdrawal and account balance inquiries) have been available from their inception, and following the same operating principles. Also, there are no relevant differences in the ATM operated by each savings bank.

The incorporation of the technology into the activities of Spanish savings banks was slow. In 1981, Spanish savings banks operated only 169 ATM terminals (one per each 52 branches). One year later, there were 522 (one per each 18 branches). In 1988, the year in which each savings bank had already adopted the ATM, 5,609 terminals formed the savings banks system, almost one per every two branches. The intensity with which each adopter incorporated the technology into its activities increased progressively over the observation window. In 1988 the average level of adoption among savings banks was 0.46 ATMs per branch. Sixteen years later, the level of adoption in the industry was 1.41 ATMs per branch. By that year, it was rare the case of a branch that did not have an ATM installed within premises.

The dataset used in this research identifies the number of ATM terminals installed by each savings bank. We set the adoption date as the oldest date in which the focal savings bank reports an operating ATM terminal, beginning in 1981 (the first year for which we have information on the diffusion of ATMs). We identify as early adopters those savings banks that by 1981 were already operating at least one ATM terminal. We define as early followers those firms that adopted the ATM in 1982. The remaining firms are defined as late adopters. At the beginning of our observation window in 1988 this classification results on a 14% of early adopters (11 firms out of 76), a 39% of early followers (30 firms) and a 46% of late adopters (35 firms). Our sample is more conservative in classifying a firm as an early mover than previous studies on FMA. For instance, Robinson et al., (1992) identify a 35% of pioneers and early entrants, 31% of early followers and 34% of late entrants. Lambkin (1988) identifies 36%, 31% and 33% within each category, respectively, in their sample of start-up industries, and 34%, 33% and 34% in their sample of adolescent industries.

5. EMPIRICAL ANALYSIS

In this section we apply the conceptual model to our research setting. In the first part of the section we explore the advantages in the time and the order of adoption. In the second part of this section we carry out the central analysis of the article. We estimate the returns that each cohort of adopters obtains and identify the different components of their advantages. We also explore the evolution of the early adopter advantages through the 17 years included in our observation window.

5.1 Advantages in time and order of adoption

Advantages in time of adoption. According to our model, in the case of externally sourced technologies advantages in time of adoption translate into higher levels of adoption than subsequent adopters. Level of adoption is measured as the average number of ATMs per branch. In Spain the vast majority of ATM terminals are installed within premises. Therefore, this measure of level of adoption captures the extent to which this technology has been incorporated into the productive activities of savings banks.

Table 1 shows the average level of adoption of each cohort of adopters for the whole observation window and different sub-periods. Early adopters show higher levels of adoption than the other cohorts in both the whole observation window and each of the sub-periods. When compared to early followers, the difference is greater in the first sub-period (1988-1991), when it was of 0.06, than in subsequent sub-periods, in which the difference falls to 0.02. Such a reduction is consistent with our contention that the advantages in time of adoption erode over time. Mean comparison tests indicate that differences in level of adoption among early adopters and early followers are not statistically significant. This may be interpreted as evidence that early followers are catching up with early adopters.

-- Insert Table 1 about here –

Early adopters also have greater levels of adoption than late adopters. During the observation window the difference increased from 0.12 (1988-1991) to 0.21 (2000-2004). Early followers also show higher levels of adoption than late adopters, with increasing differences; 0.06 between 1988 and 1991, and 0.18 between 2000 and 2004. Mean comparison tests indicate that differences in level of adoption among late adopters and the two other cohorts are significant in each sub-period.

These findings are consistent with a sigmoidal intrafirm diffusion pattern (see figure 1 on section 2.2) and with our predicted evolution of advantages in time of adoption. The data suggest that early adopters and early followers may be approaching the upper limit of their intrafirm diffusion processes, the part of the s-shape in which differences in time provide no significant differences in levels of adoption. Late adopters, in contrast, seem to be still in the middle part of the s-shape, where the slope of the intrafirm diffusion curve is large and differences in time of adoption imply significant differences on levels of adoption.

Advantages in order of adoption. In our model these advantages are translated into differences in the value captured from each level of adoption by different cohorts of adopters. The position in the order of adoption is negatively correlated to this value. Contrarily to the level of adoption, the value captured by adopters cannot be directly observed. Consequently, advantages in the order of adoption have to be estimated.

We take an accounting based financial performance measure as the dependent variable: *Returns on Assets*. It is calculated as the ratio of pre-tax profits divided by total assets, expressed in percentage points.

The key theoretical variable is *Level of Adoption*. We take level of adoption instead of a dummy for each cohort of adopters because we want to capture the returns that each adopter obtains for each unit of level of adoption. As we show above, level of adoption is correlated to order of adoption. Using dummies for each cohort would conflate order advantages with time advantages that materialize in higher levels of adoption. To estimate the different value captured by each cohort of adopters we separately introduce the level of adoption of early adopters and early followers. Late adopters are set as the base category and parameters on the level of adoption of the other cohorts represent their differential on this value, which matches our definition of advantages in order of adoption.

The estimation includes a number of control variables usual in the technology diffusion literature. Market *Concentration* is measured as the Herfindahl Index of the provinces in which each savings bank operates. Market shares are proxied through share of branches. We also control for the size of the firm and the technical unit (i.e., the branch). *Firm Size* is calculated as the logarithm of total assets. *Branch Size* is calculated as the logarithm of the ratio total assets to total branches.

The estimations also include several controls specific of the sector under analysis: *Risk* propensity (total loans to total assets) and *Inefficiency* (operating costs to operating margin). Finally, we control for technology specific factors. Number of *ATM terminals* operated by the focal firm control for potential network effects. *Relative Level of Adoption* compared to direct competitors in its local market controls for competition-based returns, and the *Density of ATMs in the Market* in which the focal firm operates controls for saturation effects (See Fuentelsaz et al, 2012). Correlations and descriptive statistics are shown in table 2.

-- Insert Table 2 about here --

We estimate two-way fixed effects models, controlling for firm and year fixed effects. We run our estimations with Ordinary Least Squares (OLS). Then, we estimate again the more suitable model with Two Stages Least Squares (2SLS) to test the robustness of our results to potential endogeneity problems. Appendix A provides a more detailed description of the specification of the model and the estimation method. The results are shown on Table 3.

-- Insert Table 3 about here --

The first column shows the baseline model that only includes the control variables. Those that are significant show the expected sign with the exception of size, which has a negative effect, and risk, for which there was no specific prediction. The negative sign of size may be a result of period specific regulatory changes. At the beginning of the observation window there was a deregulation process that, among others, allowed savings banks to expand their geographical market and go national. As a result, savings banks implemented an aggressive growth strategy in which, presumably, profitability was traded by growth (for instance, the average number of branches rose from 161 to 468).

Column 2 shows the model in which the level of diffusion of each cohort is incorporated to the model. In this model, the variable level of adoption has no significant effect on firm performance. However, in the case of early adopters and early followers the effect is positive and significant ($\beta = 0.329$, $p<0.01$ and $\beta=0.185$ and $p<0.05$, respectively). This implies that the lower the order of adoption, the greater the profitability impact of each level of adoption.

An important concern in this research is the stability of the order effect. To explore this issue in more detail, columns 3 to 6 show the interaction of the order effects with a time trend. Columns 3 to 5 show the interaction of each cohort, and column 6 shows the three interactions jointly. We find no evidence of variation over time on the advantage that stems from order of adoption. Importantly, in columns 3 and 6 there are collinearity problems in the theoretical variables (level of adoption variables and their interaction with the time trend). However, in columns 4 and 5 mean VIF is below 5.00 (3.76 and 3.86 respectively), and no variable has a VIF above 10. Therefore, the lack of significance may not be (apparently) attributed to multicollinearity[4].

Another concern in this research is the potential endogeneity of level of adoption. Column 7 checks for the robustness of the results to endogeneity in the level of adoption variables. The model is estimated by 2SLS. The estimation confirms the results.

[4] However, *finding no evidence of effect* cannot be interpreted as *finding evidence of no effect*. Therefore, we do not elaborate on this finding. In further analysis not shown here we interacted each of the level of adoption variables with time period dummies. We also estimated separate models for different sub-periods. In every case we find no relevant time patterns on the effect.

The results on this analysis indicate that early adopters obtained the greater value from each level of adoption. Early followers also obtain value from each level of adoption, but less than early adopters. Late adopters, in contrast, apparently obtain no benefit from the technology. Overall, the results confirm that there are advantages in order of adoption, as our conceptual model suggests.

5.2 Components of early adopter advantages

In this section we quantify the components of the advantages that accrue to the early adopter, and analyze their evolution between 1988 and 2004. Table 4 shows the decomposition. The panel on the left shows the advantage of early adopter versus early followers. The panel on the right shows the advantages of early adopters over late adopters. Each panel shows the total advantage and two components. The FMA component corresponds to Area II in figure 2, it is, excess returns that are obtained from pure FMAs and do not depend on differences on level of adoption. The time component depends on differences on the level of adoption as a result of differences in time of adoption. It corresponds to areas III and IV in figure 2. Each cell shows the absolute value in percentage points and the relative importance of each component respecting the total advantage. This analysis is performed for the whole observation window and for each sub-period.

-- Insert Table 4 about here –

The total advantage is calculated as the difference between the returns obtained by the early adopter (β_{EA} x LA_{EA})[5], and the returns obtained by the early follower (β_{EF} x LA_{EF}) or the late adopter (β_{LA} x LA_{LA}). As shown in table 4, early adopter advantage grows over time. This is because early adopters enjoy an advantage for each level of adoption, and the level of adoption kept growing during the observation window. In the case of early followers, the

[5] β_{EA} refers to the returns that the early adopter obtains from each level of adoption unit, as estimated in section 5.1. LA_{EA} refers to the level of adoption of the early adopter. Subscripts EF and LA refer to early followers and late adopters respectively.

advantage grew from 0.096 percent points in the period 1988-1991 to 0.201 in the period 2000-2004. In the case of late adopters, the advantage grew from 0.197 to 0.447. As expected, the advantage is greater when compared to late adopters than when compared to early followers.

The FMA component of the advantage is calculated as the excess return that the early adopter would obtain if it had the same level of adoption than the early follower [(β_{EA}-$\beta_{EF)}$ x LA_{EF})] or the late adopter [(β_{EA}-$\beta_{LA)}$ x LA_{LA})]. As shown in table 4, the absolute value of this component rose during the observation window. Against early followers, this advantage grew from 0.078 percent points in the first period to 0.192 at the end of our observation window. In the case of late adopters, the advantage grew from 0.158 to 0.378. Interestingly, this component has a different importance in each case. When calculated against early followers, the FMA component increased its importance from 80% to more than 95% of total advantage. In contrast, in the case of late adopters the FMA component does not account for more than 85% of the total advantage in any period.

The time component of the advantage is calculated as the part of the advantage that depends on differences on level of adoption, it is, the addition of area III [β_{EF} x (LA_{EA}-LA_{EF} or β_{LA} x (LA_{EA}-LA_{LA})] and area IV of the model [(β_{EA}-$\beta_{EF)}$ x (LA_{EA}-LA_{EF}) or (β_{EA}-$\beta_{LA)}$ x (LA_{EA}-LA_{LA})]. In the case of early adopter during the observation window the advantage decreased both in absolute (from 0.020 to 0.010) and in relative terms (from 20.2% to 4.9%). In the case of late adopters, this component increased in absolute value (from 0.039 to 0.069) but decreased in importance (from 20.0% to 15.4%). Therefore, this component is more important against firms that took many years to imitate than against firms that imitated within a short time period. Interestingly, we observe that this component progressively loses importance. This is because as firms reach the upper limit of their intrafirm diffusion processes differences in level of adoption tend to dissipate, reducing the importance of the time component and magnifying the importance of the FMA component.

6. DISCUSSION AND CONCLUSIONS

This article proposes a model to measure returns to early adoption of externally sourced technologies, or more precisely, the excess returns the early adopter obtains in comparison to subsequent adopters. In the model, early movers obtain advantages in order of adoption, which correspond to conventional FMAs, and advantages in time of adoption, related to the intrafirm diffusion process. As we discuss, this second kind of advantages accrue to early adopters, but does not fit in a strict definition of FMAs. In the article we analyze both kinds of advantages independently and their joint effect on excess returns.

In the case of advantages in time of adoption, we find that each cohort of adopters has persistent superior levels of adoption than subsequent cohorts of adopters. We do not argue that time since adoption determines intrafirm diffusion levels. However, everything else equal, we can expect that differences in time of adoption translate into differences in levels of adoption, and that these differences are proportional to the time lag between each cohort. These differences are critical to understand returns to early adoption, as they can be related to variations on operational performance (Devaraj and Kholi, 2003; Fuentelsaz et al, 2009) and financial performance (Fuentelsaz et al., 2012). It is important to note that the advantage in time depends on the S-shaped standard intrafirm diffusion process. Therefore, advantages in time of adoption are expected to eventually vanish as intrafirm diffusion advances and adoption levels reach the upper end of the sigmoidal pattern.

Advantages in order of adoption are the second source of advantages that we identify in our model. These advantages correspond to conventional or "pure" FMAs. We confirm that early adopters enjoy an advantage over subsequent adopters in the form of higher value obtained from each level of adoption. It is important noting that the characteristics of the intrafirm diffusion pattern require that we distinguish differences on level of adoption from pure FMAs. Therefore, it is necessary to estimate the value captured by each level of adoption, rather than considering the adoption as a "one shot" change on financial performance. Our results confirm that there are FMAs even in the conservative context of externally sourced technologies.

Our conception of FMAs adds two considerations to the literature. First, we distinguish *advantage* and *returns obtained from the advantage*. In our model, FMAs correspond to the difference in the position occupied in the Y-axis. However, returns obtained from FMAs depend both in the FMAs and on the level of adoption. Therefore, we explicitly acknowledge that a firm may enjoy FMAs, but still obtain low returns from the technology when the level of adoption is low. Only as the technology is incorporated into productive activities FMAs translate into higher returns. Second, as the intrafirm diffusion process shows a temporal pattern, also the returns obtained from FMAs will show a time pattern. As the early adopter internally diffuses the technology the returns it obtains from FMAs will grow, and the shape of these returns will be correlated to the S-shape of the intrafirm diffusion process. These two considerations may be helpful in the future to better understand the returns to early adoption and offer more accurate conclusions.

The model considers that FMAs only include those advantages that accrue strictly to the first few adopters of the technology. Later adopters may still have access to some of the FMAs isolating mechanisms, but in increasingly worse conditions. Advantages in time of adoption do not fulfill this criterion. According to the standard S-shaped intrafirm diffusion pattern, any firm can obtain time advantages respecting subsequent adopters. Therefore, these advantages are conceptually different from pure FMAs. Previous research on FMAs in different contexts may have not paid enough attention to the possibility that pioneers obtain some advantages that are not strictly FMAs. It may be valuable to elaborate additional criteria to distinguish pure FMAs from other advantages.

In our decomposition of the different components of the excess returns of early adoption we find that the FMA component is the largest by far, while the time-related component is much less relevant, and its importance decreases over time. We advanced that the time component would decrease in size and relative importance. However, there is no reason to consider a priori that the time component will be small in comparison to FMA component. In other technologies the relative importance of the components may be the opposite, with the time component being the main determinant of returns to early adoption. The main implication of this possibility is that the analysis of sustainability may change according to the importance of this component. In our context, time advantages are marginal, and as a result they have little effect on the whole advantage of the pioneers. In contexts where time advantages were central, we may see that early adopter advantages (which include both FMA and time components) erode over time due to the expected decrease on the time component.

The case of externally sourced technologies is an especially relevant research context for many reasons. First, there are many industries in which the technological regime is characterized by its heavy dependence on externally sourced technologies, such as banking or textile industries (Dolata. 2009, Pavitt. 1984). Second, small and medium sized firms are prone to externalize their innovative activities due to limited in-house innovative capabilities and R&D resources (Arora, Fosfuri and Gambardella, 2001; Hervas-Oliver et al., 2011). Third, radical new technologies frequently appear in specific industries or market niches and are later diffused into other sectors (Geels, 2002; Bunduchi et al., 2011). Firms in these other sectors usually resort to specialized technology providers to incorporate these technologies. Fourth, in the last decade markets for technology have greatly developed (Arora et al., 2001). This situation, jointly with an ever accelerating pace of technological development and increasing competition, has led organizations to increase their dependence on external sources of innovation (Cui et al.. 2009; Linder, Jarvenpaa and Davenport, 2003). Consequently, in the current competitive scenario understanding returns to early adoption of externally sourced technologies is critical for managers. We think that our findings are therefore highly informative for strategic technology management.

The results found here may be also extended to the case of new product introduction or entry into new markets. In both cases it is possible to find an analogous to our concept of level of adoption. For instance, firms may differ in their market share, volume of sales, or importance of the new product or market on aggregated activities. Interpreting our findings in terms of these analogous concepts would suggest that, rather than identifying first movers, it is necessary to quantify their commitment with the new product or market. For instance, a new product pioneer may capture only moderate rents from its pioneering position if it eventually does not achieve a high volume of sales, or if the new product is only a marginal component among its product lines. The main difference between level of adoption and those analogous is that in the case of level of adoption there is wide evidence of a time dependent intrafirm diffusion process. Thanks to its stylized time pattern we can relate differences in level of adoption with the time elapsed between adoption by different firms, and offer robust predictions on the evolution of these advantages. If it were possible to identify and demonstrate similar time patterns for market share, volume of sales or importance of the new market or product, the model suggested here may be extended to the case of new products and new markets.

APPENDIX A: Specification and estimation of the model

To determine the appropriate specification of the model we run a number of specification tests. We first run the Breusch-Pagan Lagrange Multiplier test to check for firm level unobserved heterogeneity. The test rejects the null hypothesis at $p<0.01$. This can be interpreted as evidence of firm specific effects and the need for panel data techniques (Wooldridge, 2002). Unobserved heterogeneity can take the form of fixed or random effects. To distinguish the appropriate specification we run a Hausman test. Under the null hypothesis, both fixed and random effects provide consistent estimates, but only random effects are efficient. If the Hausman test rejects the null hypothesis, only fixed effects estimations are consistent. The Hausman test rejects the null hypothesis, lending support to a fixed effects specification. Consequently, we specify a two way fixed effects model as shown in equation 1:

$$ROA_{it} = \sum_{n=1}^{k} \beta_n Variables_{it} + \theta_i + \theta_t + \varepsilon_{it} \qquad (1)$$

Where *ROA* is the dependent variable, *n* refers the *k* different explanatory variables included in the model, *i* identifies firms and *t* identifies time periods. The components θ_i and θ_t identify firm and year unobservable fixed components and ε_{it} is a random type varying effect. The other variables have previously been defined. The model is estimated by Ordinary Least Squares (OLS). Year fixed effects are controlled for with dummies. Firm effects are cancelled out with the mean deviation method.

Level of adoption may be influenced by a number of factors not explicitly modeled and for which there is no available information. Any factor not explicitly modeled is absorbed in the error term. If these omitted variables are correlated to the dependent variable, then level of adoption is correlated to the error term, and there is an endogeneity problem. As a robustness check we estimate the model using Two Stages Least Squares (2SLS).

We use internal instruments. We take three lags of the potentially endogenous variables. Lagged values are suitable instruments because they cannot be associated with unanticipated shocks in the dependent variable in the current period, which (theoretically) suffices to fulfill the orthogonality condition. We perform two tests to formally check for the appropriateness of the instruments. First, we obtain the first stage F of the instruments. It takes a value of 214.53, well above the thresholds recommended by Stock and Yogo, (2003). Consequently, the instruments are relevant. Second, we calculate the Sargan test. Under the null hypothesis, the instruments are orthogonal to the error term in the main equation. We are unable to reject the null hypothesis. Consequently, the instruments can be considered adequate (tests shown at the bottom of table 3).

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Figure 1: Standard intrafirm diffusion pattern

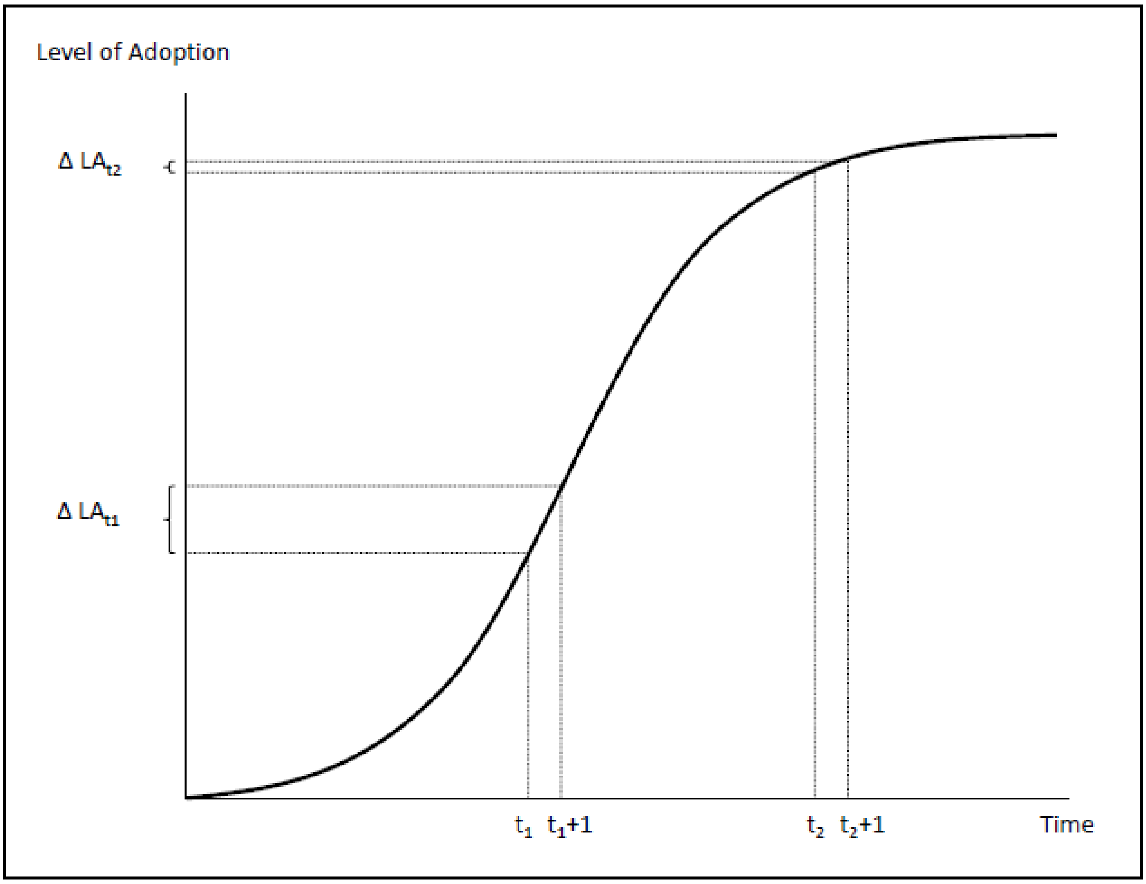

Figure 2: Components of returns to early adoption

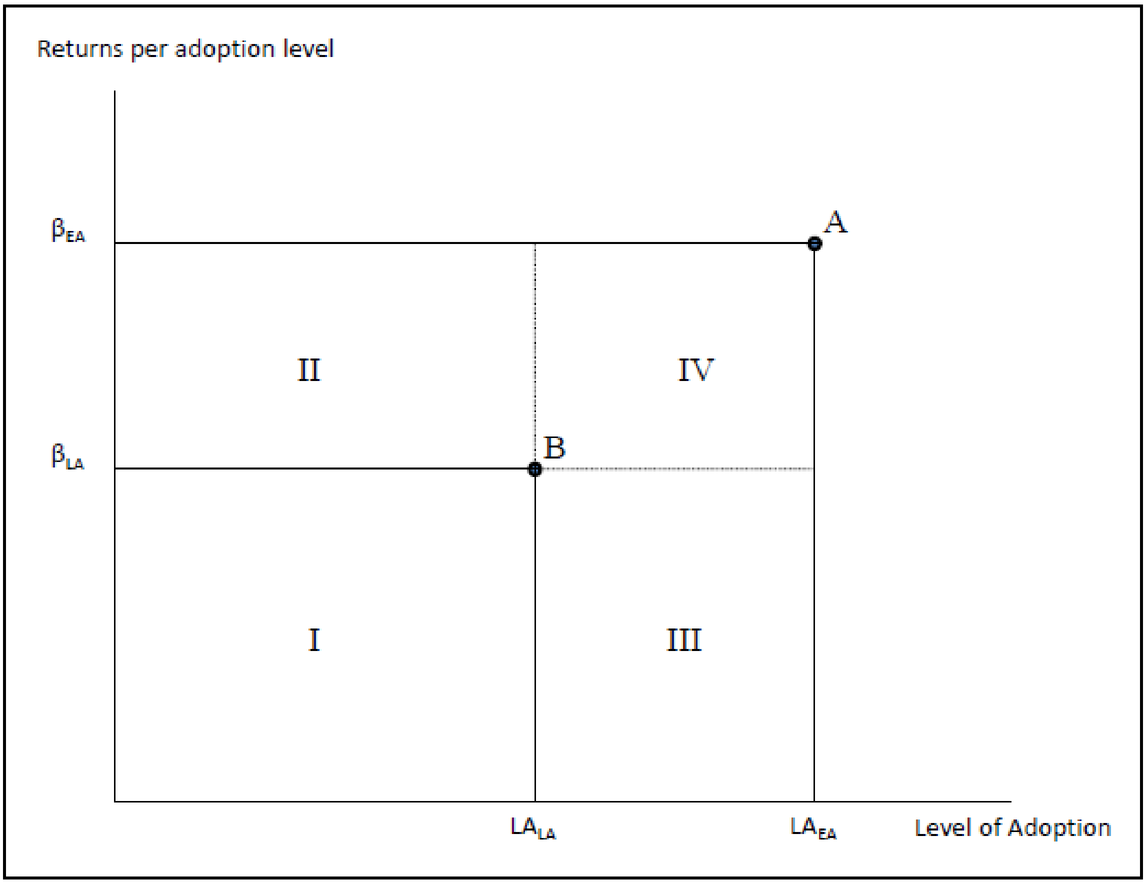

Table 1: Levels of adoption

	Early Adopters	Early Followers	Late adopters
1988-2004	1.00	0.96	0.79
1988-1991	0.60	0.54	0.48
1992-1995	0.91	0.89	0.73
1996-1999	1.13	1.11	0.96
2000-2004	1.36	1.33	1.15

Levels of adoption measured as average number of ATM terminals per branch

Table 2. Correlations and descriptive statistics

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Mean	1.09	0.90	0.16	14.17	9.01	0.56	0.57	339.85	0.91	0.46
Standard Deviation	0.52	0.47	0.08	1.29	0.43	0.13	0.08	745.79	0.21	0.25
Minimum	-2.32	0.09	0.07	10.21	7.93	0.23	0.33	2.00	0.37	0.04
Maximum	4.35	3.21	0.53	17.93	10.34	0.89	0.97	6922.00	3.04	1.06
1. Returns on Assets	1.00									
2. Level of Adoption	-0.02	1.00								
3. Concentration	0.03	-0.07	1.00							
4. Firm Size	-0.07	0.47	0.01	1.00						
5. Branch Size	0.06	0.68	0.05	0.67	1.00					
6. Risk	-0.08	0.42	-0.12	0.06	0.11	1.00				
7. Inefficiency	-0.49	-0.11	-0.03	-0.35	-0.46	0.12	1.00			
8. ATM Terminals	-0.16	0.38	-0.07	0.61	0.31	0.08	-0.01	1.00		
9. Relative Level of Adoption	-0.01	0.50	-0.06	0.33	0.41	0.00	-0.13	0.28	1.00	
10.Density of ATMs in the market	-0.10	0.56	-0.07	0.26	0.35	0.46	-0.05	0.22	-0.03	1.00

Table 3: Two-way fixed effects estimations of returns to level of adoption

Returns on Assets	(1) OLS-FE	(2) OLS-FE	(3) OLS-FE	(4) OLS-FE	(5) OLS-FE	(6) OLS-FE	(7) 2SLS-FE
Level of Adoption	-	0.031 (0.30)	-0.047 (-0.27)	0.038 (0.36)	0.045 (0.43)	0.155 (0.67)	-0.135 (-1.03)
Level of Adoption (Early Adopters)	-	0.329*** (2.93)	0.326*** (2.91)	0.336*** (2.98)	0.062 (0.25)	-0.35 (-0.12)	0.363** (2.56)
Level of Adoption (Early Followers)	-	0.185** (2.02)	0.182** (1.98)	0.092 (0.48)	0.187** (2.04)	-0.020 (-0.09)	0.188* (1.76)
Level of Adoption X Trend	-	-	0.005 (0.54)	-	-	-0.006 (-0.46)	-
Level of Adoption (Early Adopters) X Trend	-	-	-	0.004 (0.54)	-	0-017 (1.40)	-
Level of Adoption (Early Followers) X Trend	-	-	-	-	0.012 (1.19)	0.010 (0.96)	-
Concentration	-0.685 (-1.18)	-0.731 (-1.27)	-0.731 (-1.27)	-0.737 (-1.27)	-0.748 (-1.29)	-0.767 (-1.33)	-0.001 (-0.00)
Firm Size	-0.617*** (-3.70)	-0.483*** (-2.79)	-0.497*** (-2.84)	-0.482*** (-2.78)	-0.484*** (-2.79)	-0.465*** (-2.63)	-0.418** (-2.08)
Branch Size	-0.077 (-0.46)	-0.225 (-1.28)	-0.205 (-1.14)	-0.228 (-1.30)	-0.213 (-1.21)	-0.237 (-1.31)	-0.312 (-1.51)
Risk	-0.473* (-1.67)	-0.395 (-1.39)	-0.386 (-1.36)	-0.399 (-1.40)	-0.377 (-1.32)	-0.388 (-1.36)	-0.560* (-1.82)
Inefficiency	-3.007*** (-11.59)	-2.943*** (-11.43)	-2.922*** (-11.23)	-2.937*** (-11.39)	-2.939*** (-11.42)	-2.946*** (-11.31)	-3.590*** (-11.44)
ATM Terminals	-0.000 (-0.32)	-0.000 (-1.38)	-0.000 (-1.45)	-0.000 (-1.48)	-0.000 (-1.42)	-0.000 (-1.61)	-0.000 (-0.45)
Relative Level of Adoption	0.368*** (3.26)	0.261** (2.08)	0.277** (2.15)	0.267** (2.12)	0.263** (2.10)	0.261** (2.03)	0.359** (2.13)
Density of ATMs in the market	-1.713*** (-5.39)	-1.739*** (-5.46)	-1.697*** (-5.18)	-1.711*** (-5.30)	-1.742*** (-5.47)	-1.726*** (-5.25)	-0.954*** (-2.66)
Year dummies	Yes***	Yes***	Yes***	Yes***	Yes***	Yes***	Yes***
F	17.01***	15.79***	15.21***	15.22***	15.27***	14.27***	11.89***
R2	0.36	0.37	0.37	0.37	0.37	0.37	0.35
Observations	902	902	902	902	902	902	748
First stage F	-	-	-	-	-	-	214.53
Sargan Test	-	-	-	-	-	-	3.32
Wald test against (1)	-	12.65***	12.93**	13.98***	12.93**	14.89***	7.39*
Wald test against (2)	-	-	0.30	1.41	0.29	2.35	-

Robust t-ratios in parentheses

Two-tailed test of significance: * p<.10; ** p<.05; *** p<.01

Table 4: Decomposition of returns to early adoption

	Advantage against Early Followers			Advantage against Late Adopters		
	Total Advantage	**FMA Component**	**Time Component**	**Total Advantage**	**FMA Component**	**Time Component**
1988-2004	0.151 (100%)	0.138 (91.3%)	0.013 (8.7%)	0.329 (100%)	0.260 (79.0%)	0.069 (21%)
1988-1991	0.096 (100%)	0.078 (79.8%)	0.020 (20.2%)	0.197 (100%)	0.158 (80%)	0.039 (20.0%)
1992-1995	0.135 (100%)	0.128 (95.1%)	0.007 (4.9%)	0.299 (100%)	0.240 (80.2%)	0.059 (19.8%)
1996-1999	0.166 (100%)	0.160 (96.0%)	0.007 (4.0%)	0.372 (100%)	0.316 (85.0%)	0.056 (15.0%)
2000-2004	0.201 (100%)	0.192 (95.1%)	0.010 (4.9%)	0.447 (100%)	0.378 (84.6%)	0.069 (15.4%)