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Point of Sale (POS) Terminals
and the Demand for Currency

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■ Abstract

Payment cards are considered as the main drivers of the shift from paper-based towards electronic-based payment instruments, which is commonly viewed as a significant socioeconomic and welfare improvement. This shift, however, is following a slow path in many developed countries which may be, at least partially, due to the over-time overlapping of the objectives of banks in deploying automated teller machines (ATMs) and point of sale (POS) devices. In this working paper, we employ a unique database to explore these issues. The results of various empirical tests suggest that the intensity of adoption and diffusion of ATM and POS transactions is mostly driven by rival precedence, network effects and market power, while demand factors do not seem to be significant. Additionally, the growth of ATMs is found to negatively affect POS adoption. We provide estimates of the effects of these technologies on the demand for currency, showing that POS devices and higher debit and credit POS transactions may significantly reduce the demand for currency.

■ Key words

Payment cards, ATM, POS, demand for currency.

■ Resumen

Las tarjetas de pago, uno de los principales elementos determinantes de la transición de los medios de pago basados en papel a los electrónicos, representan una mejora socioeconómica y de bienestar significativa. Esta transición, sin embargo, sigue una pauta relativamente lenta en muchos países desarrollados lo que, en parte, se explica por la superposición de dos objetivos de las entidades bancarias, que tratan, por un lado, de establecer cajeros automáticos y, por otro, terminales en puntos de venta (TPV). En este documento de trabajo, se emplea una base de datos única para analizar estas cuestiones. Los resultados de varios test empíricos sugieren que la intensidad de la adopción y difusión de los cajeros y los TPV se debe principalmente a la precedencia del rival, a los efectos de red y al poder de mercado, mientras que los factores de demanda no son significativos. Asimismo, el desarrollo de los cajeros parece afectar negativa y significativamente al aumento de los TPV. Se ofrece una estimación de los efectos de estas tecnologías en la demanda de efectivo, mostrando que tanto los TPV como las tarjetas (débito/crédito) pueden reducir significativamente la demanda de efectivo.

■ Palabras clave

Tarjetas de pago, cajeros, TPV, demanda de efectivo.

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Competing Technologies for Payments:

Automated Teller Machines (ATMs), Point of Sale (POS) Terminals and the Demand for Currency

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1. Introduction

PAYMENT cards are considered as the main drivers of the shift from paper-based towards electronic-based payment instruments, which is commonly viewed as a significant socioeconomic and welfare improvement ¹. Payments systems are going through a period of rapid change with paper-based instruments increasingly giving way to electronic forms of payment. A common feature in banking systems all over the world is the deployment, in parallel, of both automated teller machine (ATM) and point of sale (POS) devices. The coexistence of both trends may be diminishing the substitution rate of cash by electronic payments in developed countries ². However the relationships and interactions between these two technologies remain largely unexplored. These relationships are not trivial and, most importantly, may pose different implications for the substitution of cash for electronic payments. On the one hand, banks typically expand ATM networks to allow cardholders to easily withdraw cash. At the same time, they also spread out their POS devices to offer cardholders a cashless method of payment at the point of sale. Banks play a key role in the payment card markets for various reasons. Firstly, banks are the main card issuers in most financial markets. Secondly, card services are usually offered as part of a set of banking products which, in turn, are frequently interrelated, in terms of costs, revenues and prices. Finally, the majority of transactions takes place at ATMs and POS machines, which are mainly provided by banks and determine a significant proportion of card network externalities.

The aim of this working paper is to analyze the adoption and interaction patterns of ATM and (debit and credit) POS transactions using bank-level

1. Based on a panel of 12 European countries during the period of 1987-1999, Humphrey, Pulley and Vesala (2006) estimate that a complete switch from paper-based payments to electronic payments could generate a total cost benefit close to 1% of the 12 nations' aggregate gross domestic product (GDP).

2. According to the data of the Bank for International Settlements, the growth rate of the real value of transactions at POS in the ten member countries of the Committee for Payment and Settlement Systems (CPSS) was 24.6%. However the real value of cash withdrawals at ATMs was growing at an annual rate of 18.0% in the same year. The CPSS members are Belgium, Canada, France, Germany, Hong Kong, Italy, Japan, Netherlands, Singapore, Sweden, Switzerland, United Kingdom and United States.

data and their effect on the substitution of cash by cards and on the demand for currency. In order to achieve this goal, the empirical analysis incorporates a number of demand and supply factors that may influence these relationships, as well as the bilateral market structure of card (two-sided) markets. The working paper is structured as follows. Section 2 analyzes the intensity of adoption and the diffusion of ATM and debit and credit POS technologies. The empirical methodology is presented in section 3. The adoption process of ATM and debit and credit POS transactions is estimated as a continuous hazard rate model while the diffusion process is estimated using Gompertz curves. The results of the adoption and diffusion processes are shown in section 4. Section 5 analyzes the effects of ATMs and POS diffusion on the demand for currency using a Baumol-Tobin model of the demand for currency. The working paper ends with a brief summary of results and conclusions in section 6.

2. The Intensity of Adoption and Diffusion Patterns of Automated Teller Machine (ATM) and Point of Sale (POS) Technologies

THE diffusion of technological innovations is a central issue in the literature of the economics of technical change. The seminal works of Griliches (1957) and Mansfield (1961) gave rise to numerous empirical studies that have analyzed the determinants of industry—and firm—specific technology adoption and diffusion³. However there are only few empirical studies examining the interaction of different technologies in the adoption and diffusion processes and, in particular, the adoption of competing and likely incompatible innovations in network industries (Katz and Shapiro, 1986; Church and Gandal, 1993; Colombo and Mosconi, 1995; Miravete and Pernías, 2006).

The adoption patterns of electronic payments delivery channels were first studied by Hannan and McDowell (1987) using a standard hazard rate (of failure-time) estimation procedure. They show that ATM innovation by rivals increases the conditional probability that a decision to adopt ATMs is made by a certain bank. The subsequent studies largely identify ATM and payment cards diffusion as an epidemic trend mainly explained by rival precedence (Ausubel, 1991; Humphrey, Pulley and Vesala, 2000; Snellman, Vesala and Humphrey, 2000; Rysman, 2007). However the intensity of the adoption of the main driver of the substitution of cash for electronic payment nowadays—the POS machine—has not yet been specifically explored,

3. See Stoneman (2001) for a comprehensive survey of the main theoretical and empirical approaches.

and its relationship with ATM adoption remains largely unknown. In many developed countries, consumers added debit cards to their wallets during the 1980s as devices to access cash at ATMs. At that time, banks aimed to move some front-desk customer services away from branches in order to increase efficiency and service. During 1990s, banks also aimed to foster the use of cards at the point of sale for purchase transactions, installing POS card payment devices. However the consumer adoption and merchant acceptance patterns of cards have been relatively slow in many countries, and the usage and diffusion of cards at ATM and POS terminals have somehow overlapped. Humphrey, Pulley and Vesala (1996) estimated a system of demand equations for five payment instruments (check, electronic or paper giro, credit card, and debit card) for 14 countries between 1987 and 1993 and found that although POS terminals and ATMs were strongly positively related to debit card usage, all payment instruments except debit cards substitute for cash. This result suggests that the use of debit cards for ATM withdrawals and POS transactions may impose some restrictions on the substitution of cash for cards. Similarly, Amromin and Chakravorti (2009) study changes in transactional demand for cash in 13 Organisation for Economic Co-operation and Development (OECD) countries from 1988 to 2003, showing that ATM withdrawals decrease with greater debit card usage at the POS.

Studies by Humphrey and Berger (1990) or Humphrey, Pulley and Vesala (2000) show that efficient payment instrument pricing induces greater use of electronic payment, as it is cheaper than paper-based payment. Nevertheless the cost advantages of cards are highly dependent on the type of card employed. In particular, Humphrey and Berger (1990) show that debit cards are significantly cheaper than cash, while credit cards are relatively expensive payment instruments. The latter deserve specific attention because their characteristics are not identical to those of debit cards. Therefore in substituting cash by cards, the distinction between debit and credit card transactions is essential. As for debit cards, enabling consumers to use debit cards is not sufficient to increase their diffusion and usage. As noted by Amromin and Chakravorti (2009), in most economies debit cards are first added—for the most part unknowingly—to consumers' wallets as a device to access cash at ATMs. With the adoption of POS machines by merchants, debit cards can be alternatively used to make purchases. Hence the final usage of debit cards will depend on consumers' attitudes as well as on the availability of POS and ATMs. Bank branches also play a role. A higher banking branch network may also reduce the use of cards at the POS since branches—together with ATMs—are the main distributors of cash.

As for credit cards, they may not be directly related to rivalry between ATM and POS card transactions but they may pose some significant indirect effects on the demand for cash since credit cards may increase consumers debt and/or permit them to move their liquidity (cash) constraints forward in time (Wright, 2004). Not surprisingly, the adoption of credit cards was found to significantly reduce currency holdings (Boeschoten, 1992). Consumers perceive credit cards as a low-cost delayed payment substitute for cash settlements. Moreover Brito and Hartley (1995) demonstrate that although borrowing on credit cards may appear irrational, due to the usually higher prices paid, such cards also provide liquidity services by allowing customers to avoid some of the opportunity costs of holding money.

In our analysis, we put together—for the first time to our knowledge—four different ingredients to explore the adoption of ATM and POS technologies at banks. The first of these ingredients is separating the influence of demand-driven and technology-driven influences in order to infer how the adoption process evolves. A second ingredient is the estimation of adoption patterns using a continuous hazard rate model. This methodology permits analyzing not just the adoption of the technological device (ATMs and POS machines) but the intensity of this adoption (the relative amount of ATM or debit/credit POS transactions over total bank transactions). A third feature refers to the industry structure itself since card payments function as networks and, therefore, the value of a network increases with every new consumer who uses cards at the own ATM or POS terminals and at any other bank that accepts them at their ATMs or POS terminals. These networks are generally organized as two-sided markets. In these markets, two (or more) parties interact on a *platform*, and the interaction involves network externalities. In the two-sided card market, the value of a network increases with every new consumer who uses cards, every merchant that accepts them at their point of sale, and any other bank that accepts them at their ATMs (Hannan et al., 2003). A fourth final ingredient is the inclusion of market power in the analysis since a pattern of diffusion will not be appropriately defined unless the ability of the providers to set prices above the marginal costs of both delivery services (ATMs and POS) is controlled for. As a consequence, the two-sided structure requires considering prices at both sides (Rochet and Tirole, 2002 and Rochet and Tirole, 2003). Therefore prices should consider all sources of card revenues including annual cardholders' fees, merchants' discount fees and interchange fees (paid by acquiring banks to issuing banks for the use of the issuers' cards at ATM and POS devices) and separate the fees that are specific to ATM transactions from those of POS transactions (Rochet and Tirole, 2003).

3. The Adoption and Diffusion Rates of Automated Teller Machines (ATMs) and Point of Sale (POS) Terminals: Determinants and Main Interactions

3.1. A continuous hazard rate model for the intensity of ATM and POS adoption

The first empirical step is the definition of a hazard rate model that distinguishes between demand-driven and technology-driven factors in the adoption of ATM and POS distribution services. The relationship follows:

$$h_i(t) = \exp(X_t'\beta), \quad (3.1)$$

where $h_i(t)$ is a continuous *hazard rate* and denotes the conditional probability that bank i will adopt the innovation during t ; X_t denotes a vector of explanatory variables relevant to period t adoptions; and β represents a vector of coefficients. Since the hazard rate is continuous rather than discrete, it is not actually a probability because it can be greater than 1. A more accurate description is that the continuous hazard rate is the unobserved rate (intensity of ATM or POS adoption in our case) at which events occur:

$$h_i(t) = \lim_{s \rightarrow 0} \frac{pr(t, t+s)}{s} \text{ with } s \rightarrow 0. \quad (3.2)$$

Because the hazard rate is continuous rather than discrete, the probability is divided by s , the length of the interval. s becomes smaller until the ratio reaches a limit. This limit is the continuous hazard rate, denoted by $h_i(t)$. In our continuous hazard rate model, we do not look at which banks

have deployed the first ATM/POS machine. Rather, we examine how intense the adoption of these devices is taking place in those banks. In particular, our dependent variable is defined by the total value of ATM (alternatively, POS) transactions divided by the sum of the total value of bank assets, ATM transactions and POS transactions. Importantly, debit and credit POS transactions are also distinguished. A first set of explanatory variables consists of demand parameters (ATM and POS transactions in $t - 1$), proxies of rival precedence (rival's ATM and POS adoption in $t - 1$), parameters showing own, and indirect network effects (*card growth x own ATMs; competitors' ATMs x own card issuance, card growth x own POS terminals, and competitors' POS terminals x own card issuance*). Similarly we report the results employing a mark-up indicator of market power, the Lerner index (the ratio *price-marginal costs/price*) applied to ATM and POS services. This involves the estimation of the marginal costs of ATMs and POS ⁴. As for the computation of prices, the price of ATM and POS transactions comprises the total revenue for ATM transactions (including ATM surcharges and fees) and POS transactions (including merchant discount fees and annual fees) divided by ATM and POS transaction value, respectively. In our analysis, we also study another type of market power indicator, the market share of ATM and POS ⁵. Finally there is a set of control variables (growth of bank ATMs, growth of bank POS terminals, total bank assets, bank branches, bank average wage, and regional gross domestic product [GDP]) and a time trend.

3.2. The diffusion processes of ATM and POS transactions: logistic and Gompertz curves

Since the hazard rate model identifies the intensity of ATM and POS transactions as a diffusion (epidemic) process, we use both logistic and Gompertz curves to consistently estimate the speed of ATM and (debit and credit) POS transaction diffusion rates over time. The linearly-transformed logistic and Gompertz models for the probability of adoption (p_t) follow, respectively:

$$\ln [p_t/(L-p_t)] = -\ln \alpha + \beta t + \varepsilon_t, \quad (3.3)$$

$$\ln [-\ln/(p_t/L)] = \ln \alpha - \beta t + \varepsilon_t, \quad (3.4)$$

4. Furthermore the cost function employed needs to be sufficiently flexible to reflect the nonlinear shape of the different marginal costs estimated. Following Pulley and Braunstein (1992), we employ the fairly flexible composite cost function to estimate the marginal costs of ATMs and POS.

5. See footnote 8.

where L is the limit for the adoption measure, pt , and is assumed to be 100%⁶. In these linear models, the estimated β proxies the speed of diffusion. Both curves are estimated using least squares with fixed effects.

3.3. Data

The data corresponds to bank-level information on ATM and POS transactions and prices from all Spanish savings banks. The sample consists of all savings banks operating in Spain from 1997:1 to 2007:4, constituting 1,980 panel observations⁷. The Spanish case is representative, since Spain is one of the world's largest ATM and POS industries⁸. All variables employed in the empirical models are described in the appendix along with the corresponding sources of data.

6. A principal difference in the two S-curve models from a forecasting standpoint is that the Gompertz model is asymmetric about its inflection point, whereas the logistic curve is symmetric.

7. These savings banks belong to two of the three competing networks in Spain (Servired and Euro6000) and are involved in approximately 60% of total card payment transactions.

8. According to the figures contained in the Blue Book on Payment and Securities Settlement Systems (European Central Bank) and the Red Book on Payment and Settlement Systems (Bank for International Settlements), in 2004 there were 55,399 ATMs and 1,055,103 POS machines in Spain. Only the United States showed a higher absolute number of ATMs and POS terminals that year.

4. Results

4.1. Results of the continuous hazard rate model

The hazard rate model is estimated using a maximum likelihood routine with fixed effects, and the results are shown in table A.2 for automated teller machines (ATMs), debit point of sale (POS) transactions and credit POS transactions. Overall the intensity of adoption is mainly driven by rival precedence (positively), network effects (positively) and market power (negatively for ATMs and positively for POS), while the influence of demand-driven factors is negligible. The case of market power is particularly interesting since it suggests that increasing margins in the ATM side—thereby increasing cardholders' ATM and/or annual fees—has a negative impact on the intensity of ATM adoption, while increasing the margins in the POS side does not seem to reduce (but to augment) the adoption of these devices⁹. The patterns of the intensity of adoption of debit and credit POS are similar with one main difference. In particular, the growth of ATM devices seems to negatively affect the intensity of adoption of debit POS technologies but not credit POS adoption. The deployment of POS terminals, however, does not seem to affect the intensity of ATM adoption.

4.2. The diffusion curves: main results and interactions

The diffusion curves of ATM and credit and debit POS transactions are explored in table A.3. By extrapolating the α and β estimates in table A.3 in the logistic and Gompertz curves, the speed of diffusion is found to be higher for ATMs than for POS over the entire estimation period. These results seem to be consistent even when the diffusion variable was interacted with four dummies—shown in rows (2) to (5) in table A.3—distinguishing the over, the median and below the median observations of rival precedence, own net-

9. The bank market share of ATMs and POS was also introduced as a measure of competition in card markets. The coefficients of these variables were not found to be statistically significant (not shown).

work effects, indirect network effects and market power. Interestingly, the speed of diffusion seems to increase when these factors are accounted for, excepting own network effects. The speed of diffusion seems to be also higher for credit than debit cards. These conclusions hold when estimation biases are controlled for using bootstrapped confidence intervals (Corradi and Swanson, 2005).

The diffusion parameters in table A.3 may be estimated at the bank level. These estimates can be viewed as the average bank-level diffusion rates for the estimated period. As a robustness check, we evaluate the impact of the rival precedence, network effects, competition and posited control factors on the estimated bank-level diffusion rates of the ATM, debit POS and credit POS. The results are shown in table A.4 and suggest that diffusion rates are mostly industry-driven, with rival precedence and network effects playing a major role. Again, while market power seems to reduce the speed of adoption of ATMs, its effect on POS diffusion is positive.

5. Automated Teller Machines (ATMs) and Point of Sale (POS) Diffusion and the Demand for Currency

PREVIOUS studies analyze the impact of currency holdings for monetary control purposes and, in particular, the distortions related to the efficient management of cash balances for consumers' transaction purposes when a (nominal) interest-bearing asset is available, using a Baumol (1952)-Tobin (1956) model of the demand for currency (e.g., Avery et al., 1986; Mulligan, 1997; Mulligan and Sala-i-Martin, 2000). Attanasio, Guiso and Japelli (2002) even consider the adoption of new transaction technologies on the demand for currency and, in particular the effects of ATM transactions. In these models, the demand for deposits—in terms of both amounts held and interest rates paid—represents the natural interest bearing asset to be considered alternative to currency. The general econometric specification of the demand for currency in the Baumol-Tobin framework is:

$$\ln (m) = \alpha - \beta t + \chi (t^2) + \delta \ln (R) + \gamma \ln (c) + \varepsilon, \quad (5.1)$$

where m is the demand for currency, t is a time trend, R is the deposit interest rates and c is the consumption in nondurable goods. In these models, the effects of new technologies are based on comparisons between users and nonusers of the technology or simply introduced as a control variable. Some studies use aggregated data (Avery et al., 1986) to estimate the demand for currency while some others use survey household or firm-level information (Mulligan, 1997). One of the main lines of inquiry in this context is the analysis of the elasticity of the demand for currency to nominal interest rates. As noted by Attanasio, Guiso and Japelli (2002) interest rates on deposits and the demand for currency overall display a remarkable degree of re-

gional variation that can be exploited to estimate the relevant elasticity of currency.

To our knowledge, these studies consider neither the effects of debit and/or credit POS transactions nor the interaction between ATM and POS transactions in the demand for currency¹⁰. In order to achieve this goal, our dataset is transformed into a regional dataset. In particular, in a first step, the demand for currency, deposit interest rates, and nondurable consumption in equation (4.1) are computed as weighted averages of the different banks in that region using the distribution of assets as a weighting factor. In a second stage, these variables are recomputed at the consumer level as ratios of the number of depositors of the banks operating in these territories¹¹. Since the available data only allow for the analysis of consumers holding deposit accounts at each bank, our estimations of the demand for currency are restricted to depositors while nondepositors are not considered¹². Additionally when averaging the variables, we consider that on average all depositors make ATM and debit and credit POS transactions. The variables are computed on an annual basis for the 17 administrative regions in Spain, which yields 187 panel observations.

The demand for currency is computed in each region as the sum of three consumer-level variables: demand deposits, ATM withdrawals, and one half of the consumption divided by the average number of deposit withdrawals¹³. The sum of demand deposits proxies the minimum amount of currency for cash withdrawals while cash withdrawals are represented by the consumption ratio and ATM withdrawals¹⁴. The mean and over-time evolu-

10. We assume that cash is the main alternative to cards while the role of checks is negligible. According to the Blue Book of Payments of the European Central Bank only 4.4% of total retail payment transactions in Spain were made by checks in 2003, and mainly for real state purchases.

11. Consumer-level variables are computed from savings bank data only. This may be a limitation that overstates the results of the demand for currency since savings banks' depositors are likely to make higher withdrawals than commercial banks' depositors. However the regional variability in the demand for currency is likely to be better captured from savings banks data since most of savings bank information can be clearly identified at the regional level while most commercial banks operate nationwide, and it is difficult to identify the source of regional variation from commercial banks data.

12. According to the Eurobarometer published by the European Commission in 2004, 10% of Spanish households do not have a deposit account.

13. This is an assumption in this type of studies, following the standard inventory model of cash management in which the determination of the optimal level of cash holdings involves a trade-off between the cost of a cash shortage and the cost of holding noninterest bearing cash.

14. Data on consumption is obtained from the Spanish Statistical Office while the average number of deposit withdrawals is obtained from savings banks information.

tion of the different variables is shown in table A.5. All variables shown in table A.5 are annual averages, excepting (demand for) currency which reflects the average currency holdings per person. All the monetary variables are deflated using the regional consumer price index. Overall the main trends show a decrease in currency holdings. Table A.5 shows that currency holdings (724 euros in 2007) are similar to international standards (Humphrey, Pulley and Vesala, 1996; Carbó, Humphrey and López, 2003), and it decreases over-time. Deposit interest rates also decrease while consumption increases during the sample period.

The main estimations of equation (4.1) are shown in table A.6. The logarithm of ATMs, POS devices, bank branches¹⁵ and regional gross domestic product (GDP) are included as control variables. ATM and POS transaction are included in a second specification while debit and credit POS transactions are considered separately in a third specification. Additionally a fourth specification controls for the intensity of cash (or alternatively, cards) usage across sectors. The latter distinction is relevant since there is significant variability in the use of cash and cards across merchants sectors. For example, the average share of cash payments in grocery stores is 92.3% while the average share of card payments in department stores is 70.9%.

The equations are estimated using a random effects panel data routine, where the regional unobservable effects are considered to be part of a composite error term and are not necessarily fixed over-time. This specification also includes time dummies. The Hausman test of random vs. fixed effects specification suggests employing a random effects procedure. Additionally the structure of equation (4.1) requires an intercept which the random effects model offers while the fixed effects model suppresses. In the first specification (column I), the elasticity of currency to deposit interest rates (-0.473) and consumption (0.202) are significant, and their values are in line with the theoretical and empirical results of previous studies based on inventory models of cash management. Importantly the deployment of ATM devices seems to increase the use of currency, although the estimated elasticity (0.009) is significantly lower compared to the negative elasticity of the deployment of POS devices (-0.462). The opening of bank branches also affects the demand for currency positively and significantly (0.349). The average number of ATM and POS transactions is included in a second specification in table A.6 (column II). The elasticity of interest rates (-0.316) and the elasticity of consumption (0.199) decrease in absolute terms. Im-

15. As in Amromin and Chakravorti (2009), bank branches is a proxy for cash access, in particular for non-ATM dispenses notes and coins.

portantly average ATM transactions affect positively and significantly the demand for currency (0.144) while POS transactions exhibit a negative and significant effect (−0.351) that almost triple that of ATM transactions. However the results suggest that as long as banks continue to deploy ATMs and POS terminals, the substitution rate of cash by cards will be diminished. As for the distinction between POS debit and credit card transactions in column III, although debit POS transactions appear to have a higher negative marginal effect on the demand for currency (−0.391), credit POS transactions also affect currency demand negatively and significantly (−0.284), suggesting that differing payments and increasing cardholders debt also reduce currency holdings significantly.

Finally column IV shows the results where the intensity of the use of cards and cash across merchant sectors are controlled for. As noted, *inter alia*, by Whitesell (1992) and Amromin and Chakravorti (2009), the choice of a payment instrument for consumption purposes (and, hence, the demand for currency) is highly dependent on merchant's acceptance. In particular, the effects of card payments on the demand for cash (for purchases) in certain merchant sectors may *per se* be invariably conditional on merchant's acceptance (related, for example, to idiosyncratic reasons and the size of payments) in that sector. In order to analyze these effects, the variables showing average ATM and POS transactions are redefined. In particular, the *the average POS transactions* variable for a certain region is computed as a weighted average of the POS transactions, using the relative weight of sectors with a high card usage as a weighting factor. Similarly average ATM transactions are computed using the reciprocal of the same weighting factor in order to show the likelihood of cash usage in sectors where cash is expected, *per se*, to show a higher usage¹⁶. The sectors where cards are found to be used to a significant larger extent than cash¹⁷ are hotels, restaurants and travel agencies; department stores and boutiques; and entertainment. The results when these variables are applied are shown in the third column of table A.6. The positive and significant effect of ATM transactions on the demand for currency seems to be higher when the composition of the nondurable consumption expenditure across merchant sectors is considered (0.266). Similarly the negative and significant effect of average POS transac-

16. The sector information is obtained from the regional consumption expenditure database of the Spanish Statistical Office

17. According to a supplementary database also provided by the Spanish Savings Banks Confederation, the use of cards in these sectors is above 65% while the median value of all sectors is 39% (not shown; available upon request).

tions—corrected for the relative weight of sectors with a high card usage—is also found to augment in absolute terms (-0.585). These results suggest that the margin to reduce the demand for currency is limited in certain sectors where the use of cash is expected to be higher. Similarly POS transactions may help reduce the demand for currency to a larger extent in those sectors where the average transaction size or the characteristics of the sector themselves make card payments more likely to occur. This may also explain why many card issuers are trying to develop specific card products for small value payments (e.g., store-value-cards or pay-as-you-go cards).

6. Conclusions

THE empirical results of this study show that the diffusion of automated teller machines (ATMs) and point of sale (POS) is found to be mostly driven by supply factors. Additionally the growth of ATM transactions is found to negatively interfere with POS diffusion. This behavior seems to be a kind of *horse race*, where banks have been typically deploying ATMs to move certain front-desk customer services away from branches although this may also have fostered cash use, thereby negatively affecting the use of cards at the merchants' point of sale. Our results suggest that this behavior is also connected with two different pricing structures for ATM and POS, in which increasing market power in the POS side does not reduce (but augment) the diffusion of these technologies while the opposite seems to occur in the case of ATMs. The results also show that the deployment of POS devices and higher POS transactions may reduce the use of currency and offset the positive effects that ATMs and ATM transactions may have on the demand for currency.

Appendix: Variable Definition and Data Sources

TABLE A.1a: Variables for the estimation of the bank-level diffusion and adoption patterns

Variable definition	
Dependent variables	
<i>Automated Teller Machine (ATM) adoption</i>	The total value of ATMs transactions divided by the sum of the total value of bank assets, ATM transactions and POS transactions.
<i>Point of Sale (POS) adoption</i>	The total value of POS transactions divided by the sum of the total value of bank assets, ATM transactions and POS transactions.
Demand	
<i>Log (ATM transactions_{t-1})</i>	Demand for ATM transactions at the beginning of the period
<i>Log (POS transactions_{t-1})</i>	Demand for POS transactions at the beginning of the period
Rival precedence	
<i>Log (rival's ATM adoption_{t-1})</i>	Rivals' precedence in the ATM market
<i>Log (rival's POS terminal adoption_{t-1})</i>	Rivals' precedence in the POS market
Network effects	
<i>Log [(card growth) x (own ATMs)]</i>	Direct ATM network effects
<i>Log [(competitors' ATMs) x (own card issuance)]</i>	Indirect ATM network effects
<i>Log [(card growth) x (own POS terminals)]</i>	Direct POS network effects
<i>Log [(competitors' POS terminals) x (own card issuance)]</i>	Indirect POS network effects

TABLE A.1a (continuation): Variables for the estimation of the bank-level diffusion and adoption patterns

Competition	
<i>Lerner index ATM transactions</i>	The difference between price and marginal cost of ATM transactions divided by the price. Prices are computed as total ATM (surcharge and fee) revenues over total ATM transactions, while marginal costs are estimated using a composite function with five outputs (loans, other earning assets, deposits, ATMs, and POS) and three inputs (deposit funding, physical capital and labor) as in Carbó, Humphrey and López (2006).
<i>Lerner index POS transactions</i>	The difference between price and marginal cost of POS transactions divided by the price. Prices are computed as total POS (merchant discount fee and annual fee) revenues over total POS transactions while marginal costs are estimated using a composite function with five outputs (loans, other earning assets, deposits, ATMs and POS) and three inputs (deposit funding, physical capital and labor) as in Carbó, Humphrey and López (2006).

Control factors	
<i>Log (growth of bank ATMs)</i>	Average growth of ATMs in the market
<i>Log (growth of bank POS terminals)</i>	Average growth of POS terminals in the market
<i>Log (total bank assets)</i>	Bank's balance sheet growth
<i>Log (bank branches)</i>	Branching network growth
<i>Log (bank average wage)</i>	Average employment costs
<i>Log (regional gross domestic product [GDP])</i>	Regional GDP in constant terms

Sources: All bank variables were obtained from reports provided by the Spanish Savings Banks Confederation. GDP and nondurable consumption were obtained from the Spanish Statistical Office.

TABLE A.1b: Variables for the cross-regional analysis of the demand for currency

	Variable definition
Dependent variable	
<i>Demand for currency</i>	Computed in each region as the sum of three consumer-level variables: demand deposits, ATM withdrawals, and one half of the consumption divided by the average number of deposit withdrawals.
Depositor level	
<i>Deposits interest rates (R)</i>	Computed as the average ratio of interest expenses to total customers' deposits of banks operating in the region.
<i>Nondurable consumption (c)</i>	Regional consumption in nondurable goods
<i>Average ATM transactions</i>	Average number of ATM transactions in the region
<i>Average POS transactions</i>	Average number of POS transactions in the region
Regional level controls	
<i>Log (ATMs)</i>	Log of total ATMs in a given region
<i>Log (POS)</i>	Log of total POS terminals in a given region
<i>Log (bank branches)</i>	Log of total bank branches in a given region
<i>Log (regional GDP)</i>	Log of regional GDP in constant terms

Sources: All bank variables were obtained from reports provided by the Spanish Savings Banks Confederation. GDP and nondurable consumption were obtained from the Spanish Statistical Office.

**TABLE A.2: Determinants of the conditional probability
of the intensity of adoption of ATMs and POS
(continuous hazard model)**
(1,980 observations)

	ATM adoption	POS adoption (debit)	POS adoption (credit)
<i>Constant</i>	-0.0628 (0.04)	-0.0561 (0.03)	-0.0558 (0.04)
Demand			
<i>Log (ATM transactions_{t-1})</i>	—	0.0215 (0.02)	0.0042 (0.02)
<i>Log (POS transactions_{t-1})</i>	0.0385 (0.02)	—	—
Rival precedence			
<i>Log (rival's ATM adoption_{t-1})</i>	0.4432*** (0.05)	—	—
<i>Log (rival's POS terminal adoption_{t-1})</i>	—	0.4631*** (0.06)	0.4942*** (0.07)
Network effects			
<i>Log [(card growth) x (own ATMs)]</i>	0.0526*** (0.01)	-0.0871*** (0.01)	-0.0618** (0.01)
<i>Log [(competitors' ATMs) x (own card issuance)]</i>	0.0018*** (0.01)	0.0062*** (0.01)	0.0071*** (0.01)
<i>Log [(card growth) x (own POS terminals)]</i>	-0.0192*** (0.01)	0.0616** (0.01)	0.0427*** (0.01)
<i>Log [(competitors' POS terminals) x (own card issuance)]</i>	-0.0084** (0.01)	-0.0051*** (0.01)	-0.0035** (0.01)
Competition			
<i>Lerner index ATM transactions</i>	-0.8028** (0.09)	—	—
<i>Lerner index POS transactions</i>	—	0.8216** (0.08)	0.8580** (0.07)

TABLE A.2 (continuation): Determinants of the conditional probability of the intensity of adoption of ATMs and POS (continuous hazard model)
(1,980 observations)

	ATM adoption	POS adoption (debit)	POS adoption (credit)
Control factors			
<i>Log (growth of bank ATMs)</i>	—	-0.0395*** (0.01)	-0.0116 (0.01)
<i>Log (growth of bank POS terminals)</i>	0.3086 (0.02)	—	—
<i>Log (total bank assets)</i>	-0.2516*** (0.05)	-0.2190* (0.06)	-0.1219* (0.05)
<i>Log (bank branches)</i>	-0.2071** (0.04)	-0.5328*** (0.05)	-0.4344*** (0.05)
<i>Log (bank average wage)</i>	0.7216** (0.06)	0.3635* (0.04)	0.3952* (0.03)
<i>Log (regional GDP)</i>	0.1658** (0.01)	0.1962** (0.01)	0.1487* (0.02)
<i>Time</i>	0.0726** (0.01)	0.0336*** (0.01)	0.0459** (0.01)
χ^2	17,63***	16,18***	16,01***

Notes:

- *, **, *** indicate p-value of 10, 5 and 1% respectively.
- ML estimation. Standard errors in parentheses.

**TABLE A.3: Estimating forecasting curves for ATM
and POS diffusion**
(1,980 observations)

		Diffusion ATM		Diffusion POS (debit)		Diffusion POS (credit)	
		Logistic	Gompertz	Logistic	Gompertz	Logistic	Gompertz
	α	1.3397** (1.29,1.35)	1.1856** (1.10,1.33)	1.7104** (1.64,1.79)	1.5662* (1.42,1.66)	1.6102** (1.54,1.76)	1.6051* (1.51,1.72)
(1)	β (<i>Time</i>)	0.0916*** (0.07,0.10)	0.0518** (0.04,0.07)	0.0622*** (0.05,0.07)	0.0599*** (0.05,0.08)	0.0715*** (0.06,0.09)	0.0599*** (0.05,0.08)
	R^2	0.87	0.84	0.80	0.81	0.88	0.81
	α	2.0125** (1.95,2.26)	1.9128* (1.76,2.09)	1.5290* (1.44,1.63)	1.2741** (1.19,1.33)	1.2420** (1.21,1.30)	1.0141** (0.90,1.18)
(2)	β (<i>Time X rival precedence</i>)	0.1552*** (0.14,0.16)	0.1015** (0.09,0.11)	0.0751** (0.06,0.09)	0.0741** (0.06,0.09)	0.0880** (0.08,0.10)	0.0663*** (0.06,0.08)
	R^2	0.90	0.84	0.83	0.90	0.87	0.88
	α	0.6029*** (0.58,0.65)	0.7355*** (0.62,0.88)	2.1315* (2.07,2.26)	1.9128** (1.82,2.02)	2.2759* (1.99,2.46)	1.8725** (1.68,1.98)
(3)	β (<i>Time X own network effects dummy</i>)	0.0890*** (0.07,0.10)	0.0778*** (0.06,0.09)	0.0982*** (0.08,0.11)	0.0665*** (0.05,0.08)	0.1643** (0.15,0.18)	0.0662** (0.06,0.08)
	R^2	0.72	0.71	0.61	0.62	0.53	0.62
	α	2.2281* (2.35,2.96)	1.6236* (1.55,1.72)	3.9055** (3.71,4.63)	1.4415** (1.36,1.62)	3.0326** (2.88,3.15)	1.4408** (1.35,1.63)
(4)	β (<i>Time X indirect network effects dummy</i>)	0.1016*** (0.08,0.11)	0.0920*** (0.08,0.10)	0.1329*** (0.12,0.15)	0.0721*** (0.06,0.08)	0.0817** (0.06,0.11)	0.0772*** (0.06,0.09)
	R^2	0.70	0.72	0.78	0.68	0.74	0.71

TABLE A.3 (continuation): **Estimating forecasting curves for ATM and POS diffusion**
(1,980 observations)

	Diffusion ATM		Diffusion POS (debit)		Diffusion POS (credit)	
	Logistic	Gompertz	Logistic	Gompertz	Logistic	Gompertz
α	3.4332** (3.02,4.13)	2.0118** (1.95,2.05)	5.2250* (4.90,5.39)	1.6084** (1.51,1.72)	3.7521** (3.51,3.95)	2.0285** (1.94,2.22)
(5) β (<i>Time X Lerner index dummy</i>)	0.1365** (0.11,0.15)	0.0885* (0.07,0.10)	0.1442*** (0.13,0.16)	0.0957** (0.08,0.11)	0.1028*** (0.09,0.12)	0.0956*** (0.08,0.11)
R^2	0.72	0.74	0.72	0.74	0.75	0.78

Notes:

- *, **, *** indicate p-value of 10, 5 and 1% respectively.
- Least squares estimates with bank fixed effects.
- Confidence intervals from bootstrapped standard errors in parentheses.

TABLE A.4: **Estimating the determinants of bank-level diffusion of ATMs and POS transactions**
(45 observations)

	β_i (Time)		
	ATM	POS (debit)	POS (credit)
<i>Constant</i>	0.0311* (0.01)	0.0202** (0.01)	0.0228** (0.01)
Demand			
<i>Log (ATM transactions_{t-1})</i>	0.1327 (0.02)	—	—
<i>Log (POS transactions_{t-1})</i>	—	0.0826 (0.03)	0.0945 (0.04)
Rival precedence			
<i>Log (rival's ATM adoption_{t-1})</i>	0.2712*** (0.02)	—	—
<i>Log (rival's POS terminal adoption_{t-1})</i>	—	0.1528** (0.02)	1442** (0.02)
Network effects			
<i>Log [(card growth) x (own ATMs)]</i>	0.0228**	-0.0216* (0.01)	-0.0363** (0.01)
<i>Log [(competitors' ATMs) x (own card issuance)]</i>	0.0481** (0.01)	0.0639* (0.02)	0.0485* (0.02)
<i>Log [(card growth) x (own POS terminals)]</i>	-0.0782* (0.02)	0.0884*** (0.01)	0.0901*** (0.02)
<i>Log [(competitors' POS terminals) x (own card issuance)]</i>	-0.0331** (0.01)	-0.0204*** (0.01)	-0.0721**

TABLE A.4 (continuation): **Estimating the determinants of bank-level diffusion of ATMs and POS transactions**
(45 observations)

	β_i (Time)		
	ATM	POS (debit)	POS (credit)
Competition			
<i>Lerner index ATM transactions</i>	-0.6061*** (0.02)	—	—
<i>Lerner index POS transactions</i>	—	0.4459** (0.02)	0.8532*** (0.02)
Control factors			
<i>Log (growth of bank ATMs)</i>	—	-0.3022** (0.01)	-0.0611 (0.03)
<i>Log (growth of bank POS terminals)</i>	0.2226 (0.03)	—	—
<i>Log (total bank assets)</i>	—	—	—
	-0.6221** (0.02)	-0.5942*** (0.01)	-0.3328* (0.01)
<i>Log (bank branches)</i>	—	—	—
	-0.1591*** (0.01)	-0.1671*** (0.01)	-0.0911* (0.02)
<i>Log (bank average wage)</i>	0.6362* (0.04)	0.2936* (0.03)	0.2853** (0.03)
<i>Log (regional GDP)</i>	—	—	—
	-0.0996** (0.01)	-0.0863** (0.01)	-0.1601** (0.02)
R^2	0.92	0.94	0.86

Notes:

- *, **, *** indicate p-value of 10, 5 and 1% respectively.
- Least squares estimates from Gompertz curve bank-level β_i .
- Explanatory variable of each bank were averaged over 44 quarters.
- Standard errors in parentheses.

TABLE A.5: Evolution of main variables of the model of the demand for currency

	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
Depositor level											
<i>Currency holdings (euros)</i>	783	771	818	807	802	793	761	754	743	732	724
<i>Deposits interest rates (%)</i>	2.28	2.06	2.02	2.00	1.91	1.74	1.66	1.56	1.84	1.78	1.75
<i>Nondurable consumption (euros)</i>	17,075	17,324	17,032	17,392	18,080	18,391	18,950	19,046	19,116	19,225	19,306
<i>Average ATM transactions (per card and year)</i>	24	25	26	26	28	29	29	30	31	31	32
<i>Average POS transactions (per card and year)</i>	7	9	11	12	14	17	20	22	25	27	28
Regional level											
<i>Log (ATMs)</i>	2.96	3.31	3.41	3.52	3.63	3.69	3.71	3.96	4.21	4.44	4.76
<i>Log (POS)</i>	4.52	4.56	4.59	4.62	4.64	4.71	4.75	5.16	5.54	5.87	6.05
<i>Log (bank branches)</i>	2.94	3.06	3.18	3.21	3.28	3.31	3.35	3.69	3.98	4.12	4.26
<i>Log (bank average wage)</i>	4.28	4.31	4.34	4.39	4.42	4.46	4.47	4.49	4.52	4.55	4.56
<i>Log (regional GDP)</i>	10.53	10.56	10.59	10.61	10.64	10.67	10.69	10.76	10.88	10.91	10.93

Notes:

- All variables are shown as annual averages excepting currency which reflects the *amount of currency usually held at home*.
- The table reports averages values from sample information.
- Nondurable consumption and currency are deflated by the consumer price index and then converted to euros.

TABLE A.6: Determinants of the demand for currency
(187 observations)

	(I)	(II)	(III)	(IV)
<i>Constant</i>	0.721** (0.020)	0.703* (0.019)	0.707** (0.018)	0.696** (0.018)
<i>Time (t)</i>	-0.122*** (0.008)	-0.125*** (0.010)	-0.122*** (0.010)	-0.118*** (0.009)
<i>Time² (t²)</i>	0.007** (0.001)	0.009* (0.001)	0.008** (0.001)	0.010* (0.001)
<i>Deposits interest rates (R)</i>	-0.473*** (0.014)	-0.316** (0.013)	-0.285* (0.012)	-0.216** (0.012)
<i>Nondurable consumption (c)</i>	0.202*** (0.017)	0.199*** (0.016)	0.208*** (0.015)	0.198** (0.021)
<i>Log (ATMs)</i>	0.009** (0.005)	0.008*** (0.006)	0.005** (0.003)	0.007*** (0.005)
<i>Log (POS)</i>	-0.462** (0.023)	-0.452*** (0.020)	-0.418** (0.019)	-0.405*** (0.015)
<i>Log (bank branches)</i>	0.349*** (0.017)	0.358*** (0.018)	0.361*** (0.017)	0.397** (0.018)
<i>Log (regional GDP)</i>	-0.018** (0.004)	-0.014** (0.005)	-0.015*** (0.008)	-0.017** (0.008)
<i>Average ATM transactions</i>	—	0.144*** (0.010)	0.129** (0.008)	—
<i>Average POS transactions</i>	—	-0.351** (0.015)	—	—
<i>Average POS debit transactions</i>	—	—	-0.391** (0.010)	—
<i>Average POS credit transactions</i>	—	—	—	—
<i>Average ATM transactions (corrected for the relative weight of sectors with a high cash usage)</i>	—	—	-0.284*** (0.009)	0.266*** (0.014)
<i>Average POS transactions (corrected for the relative weight of sectors with a high card usage)</i>	—	—	—	-0.585** (0.013)
<i>R²</i>	0.73	0.80	0.83	0.82

Notes:

- *, **, *** indicate p-value of 10, 5 and 1% respectively.
- Panel data fixed effects estimation.
- Standard errors in parentheses.
- The errors are clustered at the regional level.

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A B O U T T H E A U T H O R S *

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