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Debit card and demand for cash[☆]

Bounie David[a,*], François Abel[b], Waelbroeck Patrick[a]

[a] Telecom ParisTech, Department of Economics and Social Sciences, 46 rue Barrault, 75634 Paris Cedex 13, France
[b] University of Lille 1, Sciences et Technologie, LEM, Cité Scientifique 59655 Villeneuve d'Ascq Cedex, France

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ABSTRACT

Despite the growing importance of the debit card in most developed countries, there are relatively few academic studies that analyze the impact of such evolution on the demand for cash. Beyond data availability, this research is complicated by the fact that the debit card provides two services for consumers - cash withdrawal and payment - that have contrasting effects on cash holdings and cash usage. Using micro-level data, we estimate the impacts of both services on the demand for cash by comparing the cash holdings and cash usage of three populations, namely non-cardholders, ATM-only cardholders, and debit cardholders. Controlling for various individual and network characteristics as well as a possible endogeneity issue, we find that the negative effect of the payment service on the demand for cash dominates the positive effect of the cash withdrawal service resulting in an overall negative impact of the debit card on the demand for cash.

1. Introduction

Recent empirical research on the social cost of payments state that cash is the most costly payment instrument and that electronic ones such as debit card should be encouraged to reduce this cost (Schmiedel et al., 2012). To promote the use of debit cards, two main solutions have been considered. The first is based on a cost-related pricing of payment instruments. Since consumers do not generally face direct charges when deciding which payment instrument to use, Van Hove (2004) defends the view that there should be explicit fees, in part per-transaction, to provide information on the relative social costs of payment instruments. This solution has been implemented in Norway, for instance, to discourage the use of checks (Humphrey et al., 2001). The second solution consists of increasing the number of payment terminals at point of sale and/or limiting the number of Automated Teller Machines (ATM) to raise the costs of cash withdrawals (Snellman and Viren, 2009).

The latter solution relies on the specificity of the debit card that provides two services - cash withdrawal and payment - although from a theoretical standpoint, the two services have mixed effects on cash holdings and cash usage. Indeed, on the one hand, the cash withdrawal function of a debit card allows a consumer to withdraw cash at ATMs at a lower cost and, following Baumol (1952), the lower the cost of a cash withdrawal, the lower the cash holdings of individuals. However, since the access to cash is facilitated, the usage cost of cash is reduced with respect to alternative payment instruments, which tends to increase in turn cash usage (Whitesell, 1989). On the other hand, the payment function of a debit card avoids the costs of cash holdings and usage and then tends to reduce the demand for cash. Given these mixed effects, the question that arises concerns the final impact of the debit card on an individual's cash holdings and cash usage.

Several studies have tried to measure the effects of the debit card on the demand for cash. However, because of the scarcity of individual data, empirical studies have mainly used aggregate data leading to contrasting results. For instance, the effect of the payment function on the demand for cash is either considered as negative (Markose and Loke, 2003; Snellman et al., 2001), null (Drehmann et al., 2002) or positive (Rinaldi, 2001). To the best of our knowledge, the only empirical study that uses individual data has been conducted by Stix (2004). The author finds that ATM usage is associated with 24% lower cash holdings and that users who pay frequently with their debit card hold about 12% less cash than

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* Corresponding author.
E-mail addresses: david.bounie@telecom-paristech.fr (B. David), abel.francois@univ-lille1.fr (F. Abel), patrick.waelbroeck@telecom-paristech.fr (W. Patrick).

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infrequent users for the same value of cash transactions. However, as the study does not focus on cash usage at point of sale, the impact of the debit card on cash usage cannot be examined.

This paper precisely focuses on the extensive margin of debit cards: what happens to cash payments if a consumer adopts a debit card? This question is worthy of investigation because, contrary to common belief, the adoption of the debit card is relatively 'low' in certain developed countries. For instance, in a recent cross-country study on cash and payment cards, Bagnall et al. (2016) report that only 76% of the US population holds a debit card; this proportion amounts to 83% for France and 85% for Austria. Beyond developed countries, it is also worth noting that the penetration of the debit card remains low in many other countries such as in Eastern and Central Europe (Beck and Brown, 2011), or in East Asia and Pacific, South Asia, etc. (Agarwal, 2015). The analysis of the extensive margin of debit cards is therefore highly relevant for a significant number of countries around the world.

To analyze the extensive margin of debit cards, we use a representative survey of 1370 French individuals conducted in 2005 during which we collected daily cash payments of three distinct populations: non-cardholders, ATM-only cardholders, and debit cardholders.[1] Non-cardholders can only withdraw cash from bank branches, whereas ATM-only cardholders can also withdraw cash at ATMs but cannot pay with the ATM card. Finally, debit cardholders can withdraw cash from bank branches and/or ATMs and can, additionally, pay directly with their debit card. Using two econometric methods and controlling for various individual and network characteristics as well as a possible endogeneity issue with a Bayesian Markov Chain Monte Carlo method, we find that i. ATM-only cardholders hold lower cash balances but use more cash in payments than non-cardholders; ii. debit cardholders hold not only lower cash balances but use less cash in payments than non-cardholders and ATM-only cardholders. More precisely, we find that the availability of the withdrawal function of the debit card has a positive impact on cash payments (between +11% and +21%) and a negative effect on cash withdrawals (between −37% and −29%), whereas the payment function has a negative incidence on both cash payments (between −61% and −52%) and cash withdrawals (around −30%). Overall, the net effect of the debit card is quite negative on cash usage (around -50%) and cash withdrawals (also around -50%).

This paper contributes to the payments literature in three dimensions. First, using individual-level data, this paper is the first to clearly estimate the impact of the withdrawal and payment functions of a debit card on cash holdings and cash usage. Second, this paper proposes an original estimation method by applying Bayesian econometrics that is new to the empirical payment literature. Many previous papers that use individual-level data have analyzed the effect of credit or debit cards on an outcome variable (demand for cash, usage of cash for payments). Typically, these models are treatment effect models where the decision to hold a card is endogenous. This paper estimates an endogenous ordered probit model that deals explicitly with the existence of a potential endogeneity issue if the type of population (non-cardholder, ATM-only cardholder or debit cardholder) is correlated with unobservable variables that influence cash holdings or cash usage. Finally, this paper adapts a well-known framework of payment instrument choice (Whitesell, 1989) to derive predictions about the effects of the adoption of debit cards.

The remainder of the paper is organized as follows. In Section 2, we review the payments literature on the effects of the debit card on the demand for cash. In Section 3, we describe the French payment market and the adoption of cards. In Section 4, we develop a model that analyzes the impacts of ATM and debit cards on cash holdings and cash usage. In Section 5, we introduce the data and in Section 6, we comment on the econometric specifications and the estimation results. Finally, in Section 7, we conclude and discuss the implications of the results.

[1] This paper uses data from 2005. In light of ongoing changes (more card payments), this is a disadvantage. However, on the up-side, due to its sample size, this survey allows to find a significant number of consumers who do not hold debit and ATM cards and thus to identify the extensive margin.

2. Related literature

This section reviews the main theoretical and empirical findings on the impact of the debit card on the demand for cash.

2.1. Theoretical literature

Following the seminal paper of Baumol (1952) on the transaction demand for cash, Whitesell (1989) proposed an original approach to model the impact of the use of alternative payment instruments such as check or payment card on the demand for cash. According to Whitesell (1989), while cash holdings are subject to an interest opportunity cost, the use of cash is not subject to transaction costs (easy to use, etc.). However, the use of alternative payment instruments such as check or debit card involves fixed and variable costs in transactions. As a consequence, there is a trade-off for consumers between the opportunity cost of cash and the transaction costs for other payment instruments. Unless the opportunity cost of cash holdings is large, the author concludes that cash should be mostly used for small value transactions, i.e. where the opportunity cost is low compared with the fixed cost of other instruments. In other words, for Whitesell (1989), there is the size of a transaction, denoted λ, below which it is profitable to pay with cash.

Formally, Whitesell (1989) assumes that transactions are uniformly distributed over a continuous unit period. Let u denote the fixed cost of using a payment instrument and $v.T$ the variable cost v of a transaction size T (with $T \in]0; +\infty)$). The total cost of transacting a purchase of size T is then $u + vT$. If we denote $F(T)$ the value of spendings of size T, then the expected total cash payments are given by $S = \int_0^\lambda F(T)dT$. Let n be the number of cash withdrawals, then the size of each withdrawal is S/n and the average cash holdings equal $S/2n$. The consumer determines the number of withdrawals by minimizing the costs of withdrawals, nb (with b the cost of a single withdrawal), plus interest earnings foregone, $rS/2n$ (with r the interest rate). We can apply the same reasoning for the spendings on the interval $[\lambda; \infty)$. If $F(T)/T$ is the number of transactions in this interval, each having a transaction cost of $u + vT$, then the problem for a consumer is to choose λ and n to minimize:

$$nb + \frac{r}{2n} \cdot \int_0^\lambda F(T)dT + \int_\lambda^\infty F(T)\left[v + \frac{u}{T}\right]dT.$$

The first order conditions of this minimization problem with respect to n and λ are respectively:

$$b - \frac{rS(\lambda)}{2n^2} = 0, \tag{1}$$

and

$$\frac{rF(\lambda)}{2n} - F(\lambda)\left[v + \frac{u}{\lambda}\right] = 0. \tag{2}$$

Eq. (1) is the Baumol condition which states that the cost of cash withdrawal is just equal to the interest lost on the marginal cash withdrawal. Eq. (2) determines the level of substitution between cash and alternative payment instruments and shows that the lower the usage cost of an alternative payment instrument, the lower the use of cash (decreasing in λ).

Note also that rewriting Eq. (2) with respect to n, we have:

$$\frac{rF(\lambda)}{2}\sqrt{\frac{2b}{rS(\lambda)}} - F(\lambda)\left[v + \frac{u}{\lambda}\right] = 0. \quad (3)$$

This latter expression states that the lower the cost of a cash withdrawal the higher the share of cash payments ($S(\lambda)$).

2.2. Empirical studies

Several empirical studies have attempted to measure the impact of the use of debit and/or credit cards on the demand for cash. The contributions exploit either aggregate or individual survey data. As far as studies based on aggregate data are concerned, Rinaldi (2001) analyzes the effects of credit and debit cards, payment card terminals and ATMs on Belgian currency in circulation using time series data (1960–1999). The author finds that the number of payment card terminals and ATMs has a negative impact on currency in circulation, while a weak positive effect is found for the number of payment cards. Likewise, Snellman et al.'s 2001 panel study in 10 countries establishes that the number of debit and charge cards has an insignificant effect, whereas payment card terminals and ATMs have a significantly negative effect (the negative effect of ATMs is more than twice as large as the effect of payment card terminals). Drehmann et al. (2002) also analyze a panel of different countries and periods (1980–1998) and find that neither the number of payment terminals nor the number of ATMs has a significant effect on the demand for cash demand.

Markose and Loke (2003) also exploit aggregate data on card use in the UK (1990–1997) to calibrate a model that relates the card network coverage and the proportion of cash financed expenditures. They find that the growth of payment terminals associated with falling ATM costs has contributed to keep cash balances on a downward trend. Yazgan and Yilmazkuday (2009) analyze the effects of credit and debit cards on the currency in circulation by using monthly data for the period 2002–2006 in Turkey. They find that an increase in the usage of credit and debit cards leads to a decrease in the demand for cash.

Finally, Carbo-Valverde and Rodriguez-Fernandez (2014) use bank-level data to analyze how ATM transactions and POS transactions impact the demand for money. They find that ATM transactions and POS transactions have respectively a positive and negative significant impact on the demand for money and that the negative effect offsets the positive one of the ATM transactions.[2] As a conclusion, the use of aggregate data to examine the impact of debit cards, payment terminals and ATMs have mixed results on the demand for cash (negative, zero or positive).

To overcome these limitations, recent empirical studies have tried to use micro data based on surveys. Three of them examine the impact of a withdrawal technology on the demand for cash. Attanasio et al. (2002) estimate the demand for cash and the welfare costs of inflation for ATM-only cardholders and non-cardholders in Italy. They find that ATM users hold significantly lower cash balances than non users. Likewise, Lippi and Secchi (2009) and Alvarez and Lippi (2009) use a panel data of Italian households and confirm that agents who have access to an ATM card have lower cash balances. Finally, a last contribution proposed by Stix (2004) focuses on the impact of a withdrawal and payment technology on the demand for cash. The data source is derived from a combination of two representative surveys of 4000 individuals above the age of 15 commissioned by the Oesterreichische National bank and undertaken in March and August 2003 in Austria.

Controlling for individual variables, the results indicate that debit card usage significantly affects the demand for cash. The point estimates imply that ATM usage is associated with 24% lower cash holdings and that ATM users who withdraw frequently have about 31% lower demand for cash than non users. Finally, users who pay frequently with their debit card have about 12% less cash than infrequent users at the same value of cash transactions. To the best of our knowledge, the latter is the only study that uses individual data to assess the impact of the use of a debit card on the demand for cash.[3] Despite its significant contribution, the demand for cash is only captured by an estimated average amount of cash held in purse and does not account for the use of cash in transactions. However, according to Whitesell (1989), a decrease in the costs of cash withdrawals due to the adoption of an ATM card, for instance, can increase the use of cash in payments. In this case, the latter study can underestimate the impact of the adoption of an ATM function on the demand for cash.

The next sections are especially dedicated to the study of these effects.

3. The French payment market

In France, 99% of the population had a bank account in 2013 (Francaise, 2014). The conventional bank account pays no interest. Checks are very popular as they are free of charge (see below). The French payment card market is mature and one of the largest in the European Union. The main card scheme in France is Carte Bancaire (CB), a brand of the Groupement des Cartes Bancaires CB. By the end of 2013, CB has 126 members, comprising both banks and payment institutions worldwide and counts more than 8.6 billion payments, 1.3 million merchants, and 61.7 million cardholders.[4] As a scheme, CB does not issue cards or acquire transactions and mainly ensures total compatibility of point-of-sale payments and withdrawals at ATMs. A consumer who holds a card with a CB logo can, therefore, use his card with all merchants regardless of the merchant's bank. Likewise, a cardholder can withdraw cash at all ATMs regardless of the ATM's owner.

Three main types of CB cards are issued by banks in France: ATM cards, debit cards, and credit cards.[5] ATM cards only enable customers to access an ATM for cash withdrawals; the ATM card is not a payment card and, therefore, cannot be used to pay with. The debit card is by far the most popular with a penetration rate of over 90% in 2013 (and around 86% in 2005). The low popularity of credit cards (less than 5%), that is with a credit line, is related to the strict regulation of consumption credit. This situation is similar in a high number of European countries such as Germany, the Netherlands and Austria and, consequently, the credit card is rarely used in payments. The most up-do-date study conducted by Bagnall et al. (2016) shows, for instance, that less than 1% of all the transactions are paid with a credit card in France, 1% in the Netherlands, 2% in Germany and 2% in Austria.[6]

[2] Scholnick et al. (2008) also find that ATMs and debit cards are substitutes.

[3] Borzekowski et al. (2008) and Arango et al. (2015) also use survey data to analyze the substitution between debit and cash but do not run a separate estimation for the substitution and withdrawal effects.

[4] The corresponding figures for 2005, the year of the consumer survey, are: 6.2 billion, 1.2 million, and 58 million. The CB card is widely accepted among French retailers; for instance, 90% of retailers in the sectors such as bars/hotels/restaurants accept the CB card. However, the CB card is less accepted in specific sectors such as in 'legal activities (notaries, etc.)' where the French law often requires the use of checks, for instance, in specific transactions or in 'health' where payments are partly taken in charge by the government (see Bounie et al. (2016) for more detailed statistics).

[5] Banks can also issue ATM cards that do not carry the CB logo. In this case, the ATM card can only be used in the bank that issued the ATM card. By contrast, all the debit and credit cards carry the CB logo.

[6] Since the law named "MURCEF" in 2001, all credit cards in France must bear the words "credit card" on the card to avoid possible confusion for consumers.

Beyond ATM, debit and credit cards, French citizens also hold private label cards. The bulk of these cards are credit cards issued by non-bank companies specialized in consumer credit (such as Cetelem and Sofinco) or by retailers (such as Auchan and Galeries Lafayette). However, these cards are also infrequently used in daily payments since they can only be used in affiliated stores. For example, according to the survey that we build upon in this paper, in 2005, 97% of all the transactions were paid using cash, debit card or checks and less than 2% with CB credit cards and private label cards. For this reason, in the rest of the paper, we will ignore CB credit cards and private label cards as debit cards are largely preferred in daily payments.

4. Model

In this section, we extend the framework of Whitesell described in Section 2 to analyze the potential extent of cash substitution by debit card. We model more precisely the demand for cash of three specific populations: non-cardholders, ATM-only cardholders and debit cardholders.

4.1. General framework

Three means of payment are available for consumers, namely cash, check and debit card. We assume that all consumers have cash and checks at their disposal. In addition to these two means of payment, a consumer may use an ATM or a debit card. A consumer can use his ATM card to withdraw cash from ATMs and bank branches but cannot pay with it. The debit card allows a consumer to withdraw cash from bank branches and ATMs and also to pay with it. We have therefore three potential populations. The first, namely non-cardholder (denoted *noc*), includes people who do not hold a card; the second population, ATM-only cardholders (denoted *atm*), holds an ATM card and, the third (denoted *deb*), a debit card (debit cardholder).

Following Baumol (1952), we assume that there is a cost b to withdraw cash at ATMs (b^{ATM}) or at bank branches (b^{branch}). In our model, we assume that $b^{ATM} < b^{branch}$ as first the number of ATMs is usually larger than the number of bank branches and second cash withdrawals at bank branches last longer than those from ATMs. In line with Whitesell, we assume that each transaction carried out with a means of payment has two associated costs. Let u_i denote the fixed cost of using a means of payment i and $v_i.T$ the variable cost (or benefit) of a transaction size T (with $i = c$ for cash, $i = k$ for check and $i = d$ for debit card). We assume that the fixed costs per transaction for cash are lower than the fixed costs for card, which are lower than the fixed costs for check; formally, $u_c = 0 < u_d < u_k$. The fixed costs per transaction for check may reflect, for instance, the time to fill out a check and those of the card can be related to the time to enter the PIN code on a payment terminal. These costs do not exist for cash, which explains to a large extent the use of cash for lower-value transactions (Klee, 2008). Likewise, we assume that $v_c > v_d > v_k$. v_c is assumed to be greater than v_d and v_k because of foregone interest costs, loss of money due to the risk of theft, etc., and v_d is assumed to be greater than v_k because of the benefit of float for check. These assumptions imply first that cash is used for low value transactions because of $u_c = 0$ for which the interest earnings foregone are minimal. Second, it implies that the debit card is used for medium size transactions and check for large value transactions. These ranges of transactions are consistent with observations in France and the U.S. where cash, cards, and checks are still predominant (Bouhdaoui and Bounie, 2012; Schuh and Stavins, 2010).

Finally, let λ^d be the size of the largest transaction from which consumers prefer to use the debit card instead of cash and λ^k the size of the largest transaction from which consumers prefer to use check instead of debit card or cash.

4.2. Payment patterns of the three populations

We begin the analysis by comparing the payment behavior of the populations 1 and 2, namely non-cardholders and ATM-only cardholders. A consumer of the populations 1 and 2 is spending an amount ranging from 0 to λ^k in cash and an amount above λ^k by check; hence, the total cash spending is:

$$S(\lambda^k) = \int_0^{\lambda^k} F(T)dT,$$

and the total spending paid by check are:

$$S - S(\lambda^k),$$

with S the total spending of the consumer.

To pay with cash his expenses of a total value of $S(\lambda^k)$, a consumer needs to withdraw cash at a bank branch (population 1) or at an ATM (population 2). To determine the number of optimal withdrawals and the optimal amount of cash of each withdrawal, we follow Baumol (1952).

Let us assume that during the period, a consumer realizes n cash withdrawals. In this case, the average amount of a cash withdrawal equals $C = S(\lambda^k)/n$. Assume in addition that each withdrawal has a fixed cost b, with $b = b^{branch}$ and $b = b^{ATM}$, and a variable cost $rC/2$ related to the opportunity cost of holding cash. This opportunity cost equals the interest rate r times the average cash holdings on the period (normalized to one), $C/2$.

The consumer then chooses λ^k and the number of cash withdrawals n to minimize the costs of withdrawals and payments that can be written as:

$$\underbrace{nb + r\frac{S(\lambda^k)}{2n}}_{I} + \underbrace{\int_0^{\lambda^k} v_c F(T)dT}_{II} + \underbrace{\int_{\lambda^k}^{\infty} F(T)\left(v_k + \frac{u_k}{T}dT\right)}_{III}. \tag{4}$$

The term I in (4) represents the costs of cash withdrawals and cash holdings and the terms II and III capture the usage costs of cash and check, respectively.

The first order conditions with respect to n and λ^k are:

$$b - \frac{rS(\lambda^k)}{2n^2} = 0, \tag{5}$$

and

$$\frac{rF(\lambda^k)}{2n} - F(\lambda^k)\left[v_k - v_c + \frac{u_k}{\lambda^k}\right] = 0. \tag{6}$$

Eq. (5) states that the cost of a cash withdrawal is just equal to the interest lost on the marginal cash withdrawal. Eq. (6) determines the level of substitution between cash and check. We note n^* and λ^{k*} the optimal values of n and λ^k that verify the system of two equations with two unknowns. Rewriting Eq. (5) with respect to n, we obtain:

$$\frac{rF(\lambda^k)}{2}\sqrt{\frac{2b}{rS(\lambda^k)}} - F(\lambda^k)\left[v_k - v_c + \frac{u_k}{\lambda^k}\right] = 0. \tag{7}$$

Define:

$$G(\lambda^k, n) = \frac{rF(\lambda^k)}{2}\sqrt{\frac{2b}{rS(\lambda^k)}} - F(\lambda^k)\left[v_k - v_c + \frac{u_k}{\lambda^k}\right] = 0. \tag{8}$$

Under the assumption that the first order conditions determine a minimum, we have necessarily $\partial G/\partial\lambda^k > 0$.[7] We can, therefore,

[7] We have a minimum if the Hessien G is positive definite. If this is the case, we have necessarily $\partial G/\partial\lambda^k > 0$.

Table 1
Summary of the conclusions of the model.

	Comparison between the populations
Use of cash (S)	$\hat{S}_{atm} > \hat{S}_{noc}$
	$\hat{S}_{atm} > \hat{S}_{deb}$
	$\hat{S}_{noc} > \hat{S}_{deb}$ if $\hat{\lambda}^d_{deb} < \hat{\lambda}^k_{noc}$
Average cash withdrawal (C)	$\hat{C}_{deb} < \hat{C}_{atm}$
	$\hat{C}_{noc} > \hat{C}_{atm}$ if $\frac{b^{branch}}{b^{ATM}} > \frac{S(\hat{\lambda}^k_{atm})}{S(\hat{\lambda}^k_{noc})}$
	$\hat{C}_{deb} < \hat{C}_{noc}$ if $\frac{b^{ATM}}{b^{branch}} < \frac{S(\hat{\lambda}^k_{noc})}{S(\hat{\lambda}^d_{deb})}$

Note. noc stands for non-cardholders, *atm* for ATM-only cardholders and *deb* for debit cardholders.

apply the theorem of implicit functions which gives:

$$sgn\left\{\frac{\partial \lambda^k}{\partial b}\right\} = -sgn\left\{\frac{\partial G}{\partial b}\right\} < 0.$$

In other words, λ^{k*} is decreasing with b, meaning that consumers are likely to use less cash in payments to the benefit of checks when the cost of cash withdrawal increases. An increase in the cost of cash withdrawal has, therefore, two main effects: first, it increases the average amount of a cash withdrawal (Baumol, 1952) and, second, it decreases the use of cash in payments (Whitesell, 1989).

This result allows us to compare the value of λ^k at the equilibrium for populations 1 and 2, denoted respectively $\hat{\lambda}^k_{noc}$ and $\hat{\lambda}^k_{atm}$. Since we have $b^{branch} > b^{ATM}$, then we have $\hat{\lambda}^k_{atm} > \hat{\lambda}^k_{noc}$ and, hence, $S(\hat{\lambda}^k_{atm}) > S(\hat{\lambda}^k_{noc})$. As a result, we can conclude that ATM-only cardholders use more cash than non-cardholders.

However, the model does not allow drawing clear conclusions on the average amount of a cash withdrawal for non-cardholders and ATM-only cardholders. Indeed, at the equilibrium, the average amount of a cash withdrawal,

$$C^* = \frac{S(\lambda^{k*})}{n^*} = \sqrt{\frac{2bS(\lambda^{k*})}{r}},$$

is greater for non-cardholders than for ATM-only cardholders only if:

$$b^{branch}S(\hat{\lambda}^k_{noc}) > b^{ATM}S(\hat{\lambda}^k_{atm}).$$

This inequality is not necessarily satisfied as $b^{branch} > b^{ATM}$ and $S(\hat{\lambda}^k_{noc}) < S(\hat{\lambda}^k_{atm})$.

Finally, a consumer of the population 3, namely a debit cardholder, uses cash for amounts ranging from 0 to λ^d, debit card for amounts from λ^d to λ^k and then check for amounts above λ^k. Let us note $\hat{\lambda}^d_{deb}$ and $\hat{\lambda}^k_{deb}$, the optimal values for a debit cardholder. We have logically $\hat{\lambda}^d_{deb} < \hat{\lambda}^k_{atm}$. Indeed, if he does not use his debit card, a debit cardholder pays by check all the payments above $\hat{\lambda}^k_{atm}$. But if he does, a debit cardholder uses his debit card for amounts weakly lower or greater than $\hat{\lambda}^k_{atm}$. Using the same reasoning, we have $\hat{\lambda}^k_{deb} > \hat{\lambda}^k_{atm}$.

We can therefore conclude that $S(\hat{\lambda}^d_{deb}) < S(\hat{\lambda}^k_{atm})$ and formulate that debit cardholders use less cash than ATM-only cardholders. In addition, as the cost of a cash withdrawal is identical for debit and ATM-only cardholders, then the optimal amount of a cash withdrawal is lower for debit cardholders ($\hat{C}_{deb}$) than for ATM-only cardholders ($\hat{C}_{atm}$).

4.3. Model predictions

To summarize, our model leads to the following predictions (Table 1). To begin with, the cash payments of an ATM-only cardholder are larger than those of a non-cardholder ($\hat{S}_{atm} > \hat{S}_{noc}$) and those of a debit cardholder ($\hat{S}_{atm} > \hat{S}_{deb}$). However, the cash payments of a non-cardholder are greater than those of a debit cardholder if the size of the largest debit card purchase of a debit cardholder ($\hat{\lambda}^d_{deb}$) is strictly lower than the size of the largest check purchase of a non-cardholder ($\hat{\lambda}^k_{noc}$).

In addition, we can argue that the average cash withdrawal of a debit cardholder is lower than that of an ATM-only cardholder ($\hat{C}_{deb} < \hat{C}_{atm}$). However, there remain two undetermined relations regarding the average cash withdrawal that depends on the relationships between the costs of cash withdrawals and the size of the largest debit card and check purchases: we have $\hat{C}_{deb} < \hat{C}_{noc}$ if $\frac{b^{ATM}}{b^{branch}} < \frac{S(\hat{\lambda}^k_{noc})}{S(\hat{\lambda}^d_{deb})}$ and $\hat{C}_{noc} > \hat{C}_{atm}$ if $\frac{b^{branch}}{b^{ATM}} > \frac{S(\hat{\lambda}^k_{atm})}{S(\hat{\lambda}^k_{noc})}$.

5. Survey design and data description

In this section, we present the methodology of the survey and then the data.

5.1. Survey design

We conducted a survey from March to May 2005 in France on a representative sample of 1370 people of 18 years and older. The survey has two parts.

The first is a questionnaire designed to collect, during face-to-face interviews, payment methods, individuals' finances, socioeconomic characteristics (such as gender, age, income, and profession), and individuals' cash acquisitions. A peculiarity of the survey is that each respondent has to present during the interview the different types of card in possession (ATM, debit, and credit). Each card was then numbered and described by its features (name of the bank, nature of the card - standard, prestige, etc. - type - ATM, debit or credit - etc.). In the first page of the diary is included a summary table containing all the information (see below). Survey participants were also asked about their 'typical' or usual weekly cash withdrawals, the frequency of their cash withdrawals, and the usual places of withdrawals: ATMs, bank branches, and other sources. People may indeed obtain cash from relatives, friends, etc. These other sources are however negligible in France: only 19 people (1% of the sample) claimed that they obtained "cash from other sources".[8]

The second part is an eight-day shopping diary in which each respondent reported information on daily purchases. In the first page of the diary is included a summary table that contains all numbered cards in the respondent possession (with their characteristics). The number of a given card is then reported in the diary when the respondent claims to pay the transaction with a given card.[9] The following pages of the diary, one page per day, are related to purchases. A purchase is characterized by several pieces of information such as the size of the purchase and the payment instrument used to settle the transaction (cash, debit card - and the card number -, check or other). Therefore, we know for each individual the number and value of transactions paid with each payment instrument.

Before describing in more detail the content of the diaries, it is worth noting that transactions from diaries are representative, just like cash withdrawals, of a 'typical' period of time for each consumer (the week). To prove the efficacy of diaries in representing the actual expenses, Bagnall et al. (2016) compared, for instance, the diary outcomes in France (but also in the U.S., Canada, Germany, etc.) to aggregate expenditure data from National Accounts

[8] It is worth noting that French law prohibits the payment of wages in cash, which could explain the low percentage of respondents who obtain cash from other sources.

[9] As most French consumers just hold one card, filling the diary was not an issue.

Table 2
Description of cash withdrawals.

Population	Total weekly value of withdrawals	Average weekly number of withdrawals	Average weekly value of a withdrawal
Non-cardholders	173.0	1.1	174.7
sd	*171.9*	*1.2*	*190.9*
ATM-only cardholders	149.1	1.6	94.7
sd.	*187.0*	*1.2*	*99.2*
Debit cardholders	97.4	1.3	68.2
sd	*114.6*	*1.1*	*73.7*
Total	106.8	1.3	75.6
	128.4	*1.1*	*88.2*

Note. All figures are computed for a week; *sd* stands for standard deviation.

Table 3
Description of cash payments.

Population	Total value	Total number	Average value	Proportion of cash payments (value)	Proportion of cash payments (number)
Non-cardholders	132.2	8.0	15.3	56.4	76.6
sd	*204.7*	*5.7*	*16.0*	*38.7*	*24.7*
ATM-only cardholders	174.8	11.0	15.6	74.9	87.4
sd	*202.1*	*6.1*	*19.0*	*35.3*	*21.1*
Debit cardholders	65.9	7.1	8.9	26.4	55.3
sd	*95.6*	*5.4*	*12.1*	*29.9*	*28.0*
Total	80.1	7.4	10.0	32.7	59.6
sd	*124.6*	*5.5*	*13.4*	*34.5*	*29.0*

Note. All figures are computed for a week; *sd* stands for standard deviation.

statistics. They find that the ratio of the extrapolated diary outcomes to the aggregate consumption figures amounts to 0.88 and conclude that individual surveys performed rather well in capturing expenses made in France.[10] As a result, in line with von Kalckreuth et al. (2014) who also use diaries to explain cash usage in Germany, we are confident in the quality of the data collected and the combination of cash withdrawals and payments that derive from ‘typical’ periods of time.

5.2. Descriptive statistics

Within our sample observations, we distinguish three populations. The first consists of non-cardholders; they do not have an ATM or a debit card and they can only withdraw cash from a bank branch. This population includes 127 people (about 9% of the sample). The second population, consisting of 104 individuals, has only an ATM card (8% of the sample). This population can withdraw cash from a bank branch or at an ATM but cannot use the ATM card for a payment. Finally, the third population is composed of debit cardholders. This population is the most important with 1161 people, *i.e.* 83% of the sample, and can withdraw cash from a bank branch or at an ATM and use the debit card as a means of payment.

The description of the cash holdings of the three populations exhibits singular differences.[11] Table 2 indicates that the weekly value of cash withdrawals is higher for non-cardholders (173 euros) compared respectively with ATM (149 euros) and debit (97 euros) cardholders. Moreover, the weekly average number of withdrawals is slightly lower for non-cardholders (1.1) compared respectively with ATM (1.6) and debit cardholders (1.3) and, therefore, the average amount of a withdrawal is globally much higher for non-cardholders (175 euros compared respectively with 95 euros and 68 euros for ATM and debit cardholders).[12] These preliminary findings are quite in line with the predictions of the model described previously.

Next, it is interesting to study the cash usage of the three populations. Table 3 reports that the value of cash payments of ATM-only cardholders (175 euros) is globally greater than that of non-cardholders (132 euros) and debit cardholders (66 euros). Likewise, the average number of cash payments is also higher for ATM-only cardholders (11 compared with 8 for non-cardholders and 7.1 for debit cardholders). As a result, the average cash payment of an ATM-only cardholder (15.6 euros) is slightly higher than that of a non-cardholder (15.3 euros) and a debit cardholder (8.9 euros).[13] Table 7 in Appendix A provides further descriptive statistics about non-cardholders, ATM-only cardholders and debit cardholders.

6. Econometric method and results

In this section, we describe the empirical model based on the relationships and predictions described in Section 4 and then we

[10] Bagnall et al. (2016) calculate the total annual per-person expenditure in local currency, by multiplying the average per-person per-day expenditure figure from each diary with 365 days.

[11] In this paper, cash withdrawals are used to proxy cash holdings. The two concepts are correlated even though they are not identical. Descriptive statistics derive from the following questions: 1) “Usually, where do you withdraw cash?” [Bank branch]; [ATM]; [Other sources]; [Do not withdraw cash]; 2) “On average, how many times per week do you withdraw cash from ATMs?” and “On average, how many times per week do you withdraw cash from bank branches?” [0; 1; 2; ...7 and +]; 3) “On average, how much cash do you withdraw from ATMs?” and “On average, how much cash do you withdraw from a bank branch?” [in euros].

[12] The differences between the three populations with respect to the three variables of cash withdrawals are all significant at the 1% level except for one variable between non-cardholders and ATM-only cardholders: the difference for the value of cash withdrawal is not statistically significant at the 10% level.

[13] The differences between the three populations with respect to the five variables of cash payments are all significant at the 1% or 10% level except for one variable between non-cardholders and ATM-only cardholders: the difference for the average value of a cash payment is not statistically significant at the 10% level.

explain the econometric method. Finally, we discuss the results of the estimations.

6.1. Specification

We now describe how the impact of the debit card on cash holdings and cash usage is measured and estimated.

To begin with, we measure the level of cash holdings by the average amount of a cash withdrawal and cash usage by both the value and the share of cash payments. This strategy precisely aims at ensuring that the results are robust to various measures of cash holdings and cash usage. Three main groups of explanatory variables are used to explain cash holdings and cash usage. First of all, we use two dummy variables that indicate whether the respondent holds an ATM or a debit card (non-cardholder is thus the category of reference and is excluded from the estimations). Second, we characterize the spending of an individual by three variables: the number of purchases, the value of purchases and the value of purchases paid by check. Third, we introduce individual characteristics such as age, gender, monthly income, size of the household (in logarithm), education, profession[14], number of checking accounts and the evaluation of the risk related to cash holdings and cash usage.[15] Finally, we introduce information related to the geographical environment of the respondent to capture network effects such as the living area (rural, urban, or Paris region), the number of ATMs per square kilometer in the district of the respondent, and the number of merchants accepting the debit card (per inhabitants) in the district. To explain the average cash withdrawal, we use an additional variable: a subjective measure of the distance (in time) between the nearest bank branch and the individual's working or living place.[16]

Globally, the empirical model can be described as follows for the three measures (average cash withdrawal, value of cash payments, share of cash payments):

$$Cash_i = \beta Card_i + \delta T_i + \phi Z_i + \gamma N_i, \tag{9}$$

where $Cash_i$ takes three different measures (average cash withdrawal, value of cash payments, and share of cash payments), $Card_i =$ (Non-cardholder (Nocard), ATM-only cardholder or debit cardholder), T_i a vector of transaction characteristics (number of purchases, etc.) carried out by an individual i, Z_i a vector of individual characteristics (age, etc.) and N_i a vector of network variables (number of ATMs, etc.).[17]

6.2. Methodology

The main econometric concern with Eq. (9) deals with the existence of a potential endogeneity issue if the type of population (non-cardholder, ATM-only cardholder or debit cardholder) is correlated with unobservable variables that influence cash holdings or cash usage. To be more precise, the adoption of a specific type of card (ATM or debit card) may imply a specific use of cash. In this case, the coefficients estimated by OLS can be biased. In this section, we address this potential issue by using an endogenous ordinal probit model.

We explicitly model the correlation between the latent variable that explains the choice of holding a card or not ($Card_i$) and the measures of cash holdings or cash usage ($Cash_i$). Eq. (10) determines the outcome of the endogenous ordinal variable. We define $Card_i$ as an ordinal variable that can take on three values (the model can be easily generalized with more than three values) corresponding to the type of card.

$$Card_i = \begin{cases} Nocard & \text{if } w_i \le \alpha_1, \\ ATM & \text{if } \alpha_1 < w_i \le \alpha_2, \\ Debit & \text{if } w_i > \alpha_2, \end{cases} \tag{10}$$

with:

$$w_i = X_i\beta + \epsilon_{card,i}, \tag{11}$$

where w_i is a latent variable, β is of dimension k, and X_i is a set of control variables. We define $\alpha = (\alpha_1, \alpha_2)'$ as the vector of cutoff parameters to be estimated.

Eq. (12) explains cash usage ($Cash_i$) as a function of individual characteristics and the endogenous ordinal variable $z_{c,\,i}$ included as a set of two binary variables:[18]

$$Cash_i = z'_{c,i}\delta + V_i\gamma + \epsilon_{cash,i}, \tag{12}$$

where $z'_{c,i} = (z_{atm,i}, z_{debit,i})'$ with $z_{atm,i} = 1$ if $z_{c,i} = ATM$ (and $z_{atm,i} = 0$ otherwise), and $z_{debit,i} = 1$ if $z_{c,i} = Debit$ (and $z_{debit,i} = 0$ otherwise); the first category (Nocard) serves as reference. V_i is a set of exogenous explanatory variables that influences $Cash_i$, and δ is a vector of parameters of dimension 2. We assume that $\epsilon_i = (\epsilon_{card,i}, \epsilon_{cash,i})'$ is normally distributed with mean $(0, 0)'$ and covariance Σ for $i = 1, \ldots, n$:

$$\Sigma = \begin{bmatrix} 1 & \rho\sigma \\ \rho\sigma & \sigma^2 \end{bmatrix}. \tag{13}$$

The parameter ρ represents the correlation between the unobservable variables. Parameter σ^2 is the variance of $\epsilon_{cash,\,i}$. As the variance in Eqs. (10) and (11) is not identified, we choose to normalize the variance of the endogenous binary variable to 1. This is standard restriction in probit models (Wooldridge, 2006).

We estimate the equations using two econometric methods: OLS and Bayesian Markov Chain Monte Carlo method.[19] First, we assume that there is no endogeneity issue and estimate Eq. (11) using standard OLS. These estimates are not biased if $\rho = 0$. Second, we estimate the system of Eqs. (10), (11) and (12) using an MCMC method that can deal with the case $\rho \neq 0$.[20] The idea is to use "data augmentation" to simulate observations for the unobservable endogenous latent variable w_i of Eq. (11) and to draw simulations

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[14] We introduce a binary variable that is equal to 1 if the individual receives a portion of income in cash like bakers, craftsmen, etc., and 0 otherwise.

[15] We asked respondents the following question: "If you evaluated the risks (fraud, loss, theft, etc.) related to the holding and use of cash, where would you place it on a scale ranging from 1 to 5 (1 being less risky and 5 riskier)?"

[16] We asked the following question: "How far is the nearest bank branch from your residence or workplace? [Less than 5 minutes], [From 5 to 15mn], [From 15 to 30mn], [More than 30mn], [My bank does not have a bank branch [electronic bank]". In the estimation, we have considered that the distance was equal to 0 for people answering "electronic bank".

[17] We assume that the marginal effect of holding a debit card is the same for different socio-economic group. It would be possible to improve upon this basic framework to create interaction terms between our explanatory variables and different groups of cardholders. The small number of observations for consumers without debit card makes this approach unpractical.

[18] We decompose the ordinal variable in a set of two binary variables so that our results do not depend on the way we have coded the ordinal variable. In our application $z_{atm,\,i}$ determines whether the individual has an ATM card or not and $z_{debit,\,i}$ whether he has a debit card or not.

[19] In principle, the parameters of the system of equations could also be estimated by Maximum Simulated Likelihood where the multi-dimensional integrals appearing in the likelihood function are estimated by simulation (typically Geweke-Hajivassiliou-Keane). However, Waelbroeck (2005) and others have shown that this method provides less reliable estimates of the elements of the covariance matrix of unobservable variables than the Bayesian method. The reliability of our MCMC procedure is illustrated in Appendix D in Bounie et al. (2013) where we perform a Monte Carlo study.

[20] Bayesian MCMC methods are based on a simulation of a markov process in the parameters space (including the latent variables), which converges to a limiting distribution that it is exactly the posterior distribution of the parameters. Each parameter is simulated sequentially from its posterior conditional distribution with the Gibbs algorithm. When the exact posterior conditional distribution is not available, the Metropolis-Hastings algorithm simulates a draw by using a probabilistic acceptance method. The details of this procedure are given in Appendix B in Bounie et al. (2013).

Table 4
Cash holdings and cash usage: estimations.

Independent variables	Dependent variables		
	Average value of a cash withdrawal Coefficient (Std. Err.)	Value of cash payments Coefficient (Std. Err.)	% of cash payments Coefficient (Std. Err.)
ATM card	−37.35***(12.80)	16.91 (14.31)	11.15***(3.77)
Debit card	−67.48***(9.92)	−76.62***(10.27)	−28.79***(2.69)
Number of purchases	0.40 (0.44)	4.33***(0.51)	0.46***(0.14)
Value of purchases	0.08***(0.03)	0.44***(0.03)	0.03***(0.01)
Value of purchases paid by check	−0.04***(0.01)	−0.12***(0.02)	−0.06***(0.01)
Age	1.49***(0.17)	−0.36*(0.20)	−0.18***(0.05)
Sex (1 if female)	2.72 (5.17)	−1.02 (6.01)	5.67***(1.57)
Monthly income: < 1000€	Ref	Ref	Ref
1000 to 3000€	4.55 (5.88)	−7.14 (6.81)	−8.30***(1.78)
> 3000€	−1.72 (9.14)	−30.00***(10.61)	−9.84***(2.78)
refusal/do not know	6.41 (8.68)	−6.02 (9.70)	−4.44*(2.54)
Log(size of household)	10.68**(4.81)	6.38 (5.74)	−2.16 (1.50)
Education: no diploma	Ref	Ref	Ref
before university	9.30 (7.53)	−22.55***(8.49)	−13.35***(2.23)
university	−1.35 (8.98)	−33.83***(10.38)	−18.96***(2.72)
Profession (paid in cash)	29.95*(17.53)	1.33 (18.15)	−1.67 (4.74)
Living area: rural	Ref	Ref	Ref
Living area: urban	9.24*(5.43)	16.40***(6.27)	4.67***(1.64)
Living area: paris and around	8.24 (10.54)	27.09*(12.52)	5.91*(3.27)
ATM per km^2	0.01 (0.01)	0.01 (0.01)	0.001 (0.004)
Nb of merchants accepting the debit card per inhab.	−0.12 (1.17)	−2.09 (1.35)	−0.17 (0.35)
Number of checking accounts	1.75 (4.71)	−10.26*(5.27)	−4.94***(1.38)
Log(risk)	−5.25 (4.10)	−5.63 (4.78)	−1.73 (1.25)
Distance from bank branch: < 5 mn	Ref	Ref	Ref
[5 mn; 30 mn]	3.38 (5.66)	–	–
> 30 mn	5.22 (10.68)	–	–
Intercept	38.08*(22.25)	139.60***(25.19)	87.06***(6.60)
N	1151	1389	1383
R^2	0.14	0.30	0.37

Note. Significance levels: * : 10% ** : 5% *** : 1%

from the full posterior distribution of α, β, δ, γ, ρ, σ, and w_i.[21] Indeed, once we observe or simulate w_i in Eq. (11), the system of Eqs. (11) and (12) is a simple Seemingly Unrelated Regression model (SUR). Similarly, once w_i is observed, we can easily make inference on parameters α_1 and α_2 in Eq. (10) (Poirier and Tobias, 2007). However, we are not aware of any studies that deal with Eqs. (10), (11), and (12) simultaneously. This is an additional contribution of the present paper. Details of the MCMC algorithm are given in Appendix B in Bounie et al. (2013).

6.3. Results of the estimations

We estimate the coefficients of Eqs. (10), (11), and (12) using the MCMC algorithm; results are provided in Table 8 in Appendix C. In particular, the correlations between the unobservable variables (ρ) are estimated at −0.024 for the cash holdings and from −0.024 to −0.051 according to the measures of cash usage and are all not significantly different from 0. Since these correlations measure the extent of the endogeneity issue, we can conclude that the results obtained with the MCMC algorithm are quite similar to the OLS method.[22] We therefore decide to comment on the estimations produced with the standard OLS given in Table 4.

Globally, the model has good explanatory power and the estimations provide strong support to the model. First, the point estimates imply that non-cardholders are associated with higher cash balances than people with ATM or debit cards. For instance, a non-cardholder respectively withdraws 37.4 euros and 67.5 euros more than ATM and debit cardholders. Likewise, ATM-only cardholders have higher cash balances than debit cardholders. These findings are quite in line with the predictions of the model as we proved that $\hat{C}_{atm} > \hat{C}_{deb}$. Second, the estimations about the two other measures of cash usage also confirm the theoretical predictions. Compared with non-cardholders, holding an ATM card increases the value of cash payments and the share of cash payments by 16.9 euros (although it is non significant) and 11.2% (significant at the 1% level). This result confirms, therefore, that $\hat{S}_{atm} > \hat{S}_{noc}$. We also note significant differences between non-cardholders and debit cardholders: the value of cash payments and the share of cash payments decreases by 76.6 euros and 29 points of percentage for debit cardholders compared with non-cardholders. Once again, following the notations of our model, $\hat{S}_{noc} > \hat{S}_{deb}$ which implies that the largest debit card purchase of a debit cardholder ($\hat{\lambda}^d_{deb}$) is strictly lower than the size of the largest check purchase of a non-cardholder ($\hat{\lambda}^k_{noc}$).

To illustrate these findings, we perform simulations and calculate the predicted values of our three dependent variables (cash holdings and cash usage) for each of the three populations (non-cardholders, ATM-only cardholders, and debit cardholders). The results are summarized in Table 5.

$\bar{y}_{noc}$ denotes the sample average of cash payments of non-cardholders, and $\bar{\hat{y}}^{atm}_{noc}$ and $\bar{\hat{y}}^{deb}_{noc}$ refer to the predicted cash usage of non-cardholders if they were equipped with an ATM or a debit card. Table 5 displays the average of the considered predicted value (with $\hat{hat}$) that we can compare with its true sample value (in

[21] Data augmentation exploits the latent variable structure of multinomial probit models by simulating the latent variables from truncated normal distributions, generating additional data. The full posterior distribution of the parameters and of the latent variables is much simpler to analyze.

[22] Although the correlation between the unobserved variables is not significantly different from 0, endogeneity can be an issue in other data sets. We perform a Monte Carlo study with simulated data in Appendix D in Bounie et al. (2013) and show that OLS estimates of the system of equations can lead to strong biases even with a correlation of 0.6 between the unobserved variables. The Bayesian estimates are much more reliable as they are close to the true values of the parameters that generated the simulated data.

Table 5
Average effective and predicted values for non-cardholders, ATM and debit cardholders.

Population	Measure of cash use	Predictions of cash demand for:					
		Non-cardholders		ATM-only cardholders		Debit cardholders	
Non-cardholders	Value of cash payments	$\bar{y}_{noc} =$	*132*	$\bar{\hat{y}}^{atm}_{noc} =$	150	$\bar{\hat{y}}^{deb}_{noc} =$	56
	% of cash payments		*56*		68		28
	Average cash withdrawal		*175*		110		78
ATM-only cardholders	Value of cash payments	$\bar{\hat{y}}^{noc}_{atm} =$	158	$\bar{y}_{atm} =$	*175*	$\bar{\hat{y}}^{deb}_{atm} =$	82
	% of cash payments		64		*75*		36
	Average cash withdrawal		133		*95*		66
Debit cardholders	Value of cash payments	$\bar{\hat{y}}^{noc}_{deb} =$	142	$\bar{\hat{y}}^{atm}_{deb} =$	160	$\bar{y}_{deb} =$	*66*
	% of cash payments		55		66		*26*
	Average cash withdrawal		137		100		*68*

Note. $\bar{y}_{noc}, \bar{y}_{atm}, \bar{y}_{deb}$: average effective values for non-cardholders, ATM and debit cardholders.
$\bar{\hat{y}}^{atm}_{noc}, \bar{\hat{y}}^{deb}_{noc}$: average predicted values for non-cardholders equipped with an ATM or a debit card.
$\bar{\hat{y}}^{noc}_{atm}, \bar{\hat{y}}^{deb}_{atm}$: average predicted values for ATM-only cardholders equipped or not with a debit card.
$\bar{\hat{y}}^{noc}_{deb}, \bar{\hat{y}}^{atm}_{deb}$: average predicted values for debit cardholders equipped or not with an ATM card.
Figures in italic indicate effective average values and others refer to average predicted values.

Table 6
Impacts of the withdrawal and payment functions of the debit card.

Effect of:	Variables	On the value of cash payments (%)	On the share of cash payments (%)	On the average cash withdrawal (%)
The withdrawal function	$\bar{\hat{y}}^{atm}_{noc} - \bar{y}_{noc}$	+14	+21	−37
(*Non-cardholders/ATM-only cardholders*)	$\bar{y}_{atm} - \bar{\hat{y}}^{noc}_{atm}$	+11	+17	−29
The payment function	$\bar{\hat{y}}^{deb}_{atm} - \bar{y}_{atm}$	−53	−52	−30
(*ATM/Debit cardholders*)	$\bar{y}_{deb} - \bar{\hat{y}}^{atm}_{deb}$	−59	−61	−32
Both functions	$\bar{\hat{y}}^{deb}_{noc} - \bar{y}_{noc}$	−58	−50	−55
(*Non-cardholders/Debit cardholders*)	$\bar{y}_{deb} - \bar{\hat{y}}^{noc}_{deb}$	−53	−53	−50

Notations are similar to Table 5.

italics).[23] It transpires that if non-cardholders were equipped with an ATM card, their cash usage would be higher, captured either by the share of cash payments (from 56 to 68 euros) or the value of cash payments (from 132 to 150 euros), and they would hold lower cash balances (from 175 to 110 euros). As a result, we can conclude that holding an ATM card gives greater access to cash and increases cash usage. By contrast, Table 5 also shows that if non-cardholders and ATM-only cardholders were equipped with a debit card, their cash holdings and cash usage would be much more lower. As an illustration, if ATM-only cardholders were equipped with a debit card, their value of cash payments would drop from 175 to 82 euros, and they also would hold lower cash balances (from 95 to 66 euros).

7. Concluding remarks

This paper aimed at estimating the impact of the adoption of a debit card on cash holdings and cash usage. Estimation results strongly support the theoretical predictions of the model: if the withdrawal function of a card decreases cash holdings and increases cash usage, the payment function of a debit card significantly reduces cash holdings and cash usage. The debit card can therefore be considered as a perfect substitute for cash.

Using the results obtained and summarized in Table 5, we can precisely assess the effects of the withdrawal and payment functions of a debit card on cash holdings and cash usage by comparing the three populations, namely non-cardholders, ATM-only cardholders, and debit cardholders. Table 6 summarizes the findings.

To begin with, we find that the withdrawal function of an ATM card decreases the level of cash holdings by approximately one-third but increases cash usage by 11–21% when we compare ATM-only cardholders with non-cardholders. Next, comparing debit cardholders to ATM-only cardholders, we note that the payment function of a debit card decreases the use of cash in payments by about a half and the cash holdings by about one-third. Thus, we can conclude that if the withdrawal function of a card increases cash holdings, the payment function decreases not only cash holdings but also cash usage. To give an idea of the extent of this effect, we can compare the behaviors of non-cardholders with those of debit cardholders. The last lines of Table 6 confirm that the cash holdings of debit cardholders decrease by half compared with non-cardholders, while cash usage also decreases by half. As a result, the debit card drastically reduces cash holdings and cash usage.

Beyond the academic interest of this research, it is worth noting that these findings have practical implications for commercial banks and competition authorities. Indeed, delivering a debit card to non-cardholders and ATM-only cardholders can help commercial banks to reduce the costs of cash in the economy and then the social cost of payments. Indeed, delivering cash is by nature costly for commercial banks because they do not perceive the benefits of issuing cash - seigniorage goes to the central bank - while they incur the costs of delivering cash through ATMs and bank branches; in addition, the use of cash by consumers reduces bank deposits and then potential interest revenues from lending activities. On the other hand, issuing debit cards can generate revenues

[23] We calculate the statistics as follows. On each sub-population (non-cardholders, ATM-only cardholders and debit cardholders), we apply the empirical model estimated over the overall population. Next, we vary the value of the dummy variables regarding to the type of card to simulate the changes in card holding. We average the predicted values of the three dependent variables. We finally obtain the predicted values of cash usage and cash holdings while considering the sub-population characteristics.

Table 7
Statistical description of the sub-populations.

Variables	Non-cardholders	ATM-only cardholders	Debit cardholders
Number of purchases (average)	10.28	12.56	12.11
Value of purchases (average)	68.30	75.14	83.75
Value of purchases paid by check (average)	128.42	67.69	111.39
Age (average)	51.98	41.03	44.42
Sex (1 if female) (average)	0.42	0.36	0.44
Monthly income: < 1000€ (percent)	51.97	52.88	34.19
1000 to 3000€ (percent)	25.20	25.00	41.95
> 3000€ (percent)	3.94	9.62	12.06
refusal/do not know (percent)	18.90	12.50	11.80
Log(size of household) (average)	0.83	0.92	0.90
Education: no diploma (percent)	27.56	62.20	10.24
before university (percent)	30.77	63.46	5.77
university (percent)	11.63	63.39	24.98
Profession (paid in cash) (average)	0.04	0.03	0.02
Living area: rural (percent)	44.88	42.52	12.60
Living area: urban (percent)	39.42	43.27	17.31
Living area: paris and around (percent)	41.43	44.53	14.04
ATM per km^2 (average)	66.53	88.82	
Nb of merchants accepting the debit card per inhab. (average)	11.76	12.37	12.54
Number of checking accounts (average)	1.26	1.20	1.34
Log(risk) (average)	0.60	0.67	0.71
Distance from bank branch: < 5 mn (percent)	25.20	26.92	26.36
[5 mn; 30 mn] (percent)	67.72	68.27	67.10
> 30 mn (percent)	7.09	4.81	6.55
N	127	104	1,161

from fees and subscriptions from consumers and merchants. The development of the debit card in most economies is probably related in part to these advantages.[24]

Appendix A: descriptive statistics

See Table 7.

Appendix B: estimation method to account for the endogeneity issue

Eq. (14) determines the outcome of the endogenous ordinal variable. We define $y_{1,\,i}$ as an ordinal variable that can take on J values (in our application $J = 3$).

$$y_{1,i} = \begin{cases} 1 & \text{if } w_{1,i} \le \alpha_1, \\ \dots & \\ j & \text{if } \alpha_{j-1} < w_{1,i} \le \alpha_j, \\ \dots & \\ J & \text{if } w_{1,i} > \alpha_{J-1}, \end{cases} \tag{14}$$

where $w_{1,i} = x_{1,i'}\beta_1 + \epsilon_{1,i}$, β_1 is of dimension k_1 and $x_{1,\,i}$ is a set of control variables. We define $\alpha = (\alpha_1, \dots, \alpha_{J-1})'$ as the vector of cutoff parameters to be estimated.

Eq. (15) explains the cash payments $w_{2,\,i}$ as a function of individual characteristics and the endogenous ordinal participation variable $y_{1,\,i}$ included as a set of $J-1$ binary variables:[25]

$$w_{2,i} = z'_{2,i}\gamma_2 + z'_{1,i}\delta_2 + \epsilon_{2,i} = x'_{2,i}\beta_2 + \epsilon_{2,i}, \tag{15}$$

where $z_{1,i} = (z_{1,2,i}, \dots, z_{1,J,i})'$ with $z_{1,j,i} = 1$ if $y_{1,i} = j$ (and $z_{1,j,i} = 0$ otherwise, $j = 2, \dots, J$), δ_2 is a vector of parameters of dimension $J-1$, $x_{1,i} = (z_{2,i}, z_{1,i})'$ and $\beta_2 = (\gamma'_2, \delta_2)'$.

We assume that $\epsilon_i = (\epsilon_{1,i}, \epsilon_{2,i})'$ is normally distributed with mean $(0, 0)'$ and covariance Σ for $i = 1, \dots, n$:

$$\Sigma = \begin{bmatrix} 1 & \rho\sigma \\ \rho\sigma & \sigma^2 \end{bmatrix}. \tag{16}$$

The parameter ρ represents the correlation between the unobservable variables. Parameter σ^2 is the variance of $\epsilon_{2,\,i}$. Since the ordinal probit model in Eq. (14) is not identified, we choose to normalize the variance of the endogenous binary variable to 1. This is standard restriction in probit models (Wooldridge, 2006).

Let $\beta = (\beta'_1, \beta'_2)'$, $w_1 = (w_{1,1}, \dots, w_{1,n})'$, $w_2 = (w_{2,1}, \dots, w_{2,n})'$ and define $w = (w'_1, w'_2)'$. We define ϵ_1, ϵ_2, and ϵ in a similar way.

The covariance of the unobservable variables is simply:

$$\Omega = E\epsilon\epsilon' = \Sigma \otimes I_n,$$

where I_n denotes the identity matrix of dimension $n \times n$ and E is the expectation sign. Thus Ω^{-1} is readily obtained. Similarly, we define:

$$X = \begin{bmatrix} x_1 & 0 \\ 0 & x_2 \end{bmatrix}, \tag{17}$$

of dimension $2n \times (k_1 + k_2)$.

The (partially) latent model can be written in matrix format:

$$w = X\beta + \epsilon. \tag{18}$$

Hence, conditional on w and Ω, the estimates of β are simply obtained by a Generalized Least Squares (GLS) regression of Eq. (17).[26] Moreover, the matrices $X'\Omega^{-1}X$ and $X'\Omega^{-1}w$ required for the GLS estimates of the parameters of the model are easily computed.

Appendix C: estimations results with endogeneity issue

See Table 8

[24] A further major advantage for the economy of cards versus cash is eliminating the possible anonymity of transactions, reducing in turn the illegal economic activity.

[25] We decompose the ordinal variable in a set of binary variables so that our results do not depend on the way we have coded the ordinal variable. This is not an issue in Eq. 11 since the methodology automatically determines the cut-off points regardless of the values of the ordinal variable.

[26] Since each stage generally includes different sets of explanatory variables, we cannot estimate the SUR model with ordinary least squares regression applied to each latent equation separately.

Table 8
Estimation of cash usage and cash holdings with endogeneity issue.

Independant variable	Average value of a cash withdrawal coef. (s.e.)	Value of cash payments coef. (s.e.)	% of cash payments coef. (s.e.)
	Estimation of the type of card		
Age	−0.001 (0.003)	−0.005 (0.002)	−0.005 (0.002)
Living area: rural	*Ref (-)*	*Ref (-)*	*Ref (-)*
Living area: urban	0.057 (0.100)	−0.002 (0.087)	−0.004 (0.088)
Living area: paris and around	−0.196 (0.133)	−0.163 (0.125)	−0.165 (0.126)
Education: no diploma	*Ref (-)*	*Ref (-)*	*Ref (-)*
Education: before university	0.546 (0.117)	0.475 (0.102)	0.472 (0.102)
Education: university	1.118 (0.164)	1.031 (0.146)	1.027 (0.147)
Distance from bank branch: $<$ 5 mn	*Ref (-)*	*Ref (-)*	*Ref (-)*
Distance from bank branch: [5 mn; 30 mn]	0.043 (0.104)	0.013 (0.093)	0.008 (0.093)
Distance from bank branch: $>$ 30 mn	0.200 (0.214)	0.004 (0.183)	−0.008 (0.185)
Intercept	0.985 (0.197)	1.112 (0.174)	1.122 (0.175)
$\alpha 1$	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
$\alpha 2$	0.474 (0.047)	0.384 (0.035)	0.380 (0.036)
	Estimation of cash use		
ATM card	−36.404 (13.578)	18.807 (15.000)	10.732 (4.585)
Debit card	−63.042 (17.135)	−70.313 (17.803)	−25.520 (8.523)
Number of purchases	0.395 (0.438)	4.348 (0.510)	0.534 (0.135)
Value of purchases	0.084 (0.028)	0.438 (0.031)	0.027 (0.008)
Value of purchases paid by check	−0.038 (0.014)	−0.120 (0.017)	−0.064 (0.004)
Age	1.488 (0.175)	−0.373 (0.198)	−0.184 (0.053)
Sex (1 if female)	2.795 (5.164)	−0.767 (6.023)	5.495 (1.576)
Monthly income: $<$ 1000€	*Ref (-)*	*Ref (-)*	*Ref (-)*
Monthly income: 1000 to 3000€	4.407 (5.867)	−7.729 (6.824)	−8.006 (1.795)
Monthly income: $>$ 3000€	−1.748 (9.149)	−30.174 (10.639)	−9.510 (2.800)
Monthly income: refusal/do not know	6.332 (8.709)	−6.047 (9.740)	−4.012 (2.564)
Log(size of household)	10.658 (4.825)	6.100 (5.750)	−1.919 (1.516)
Education: no diploma	Ref (-)	Ref (-)	Ref (-)
Education: before university	8.583 (7.808)	−23.710 (8.725)	−12.785 (2.496)
Education: university	−2.394 (9.503)	−35.414 (10.856)	−18.777 (3.266)
Profession (paid in cash)	30.169 (17.459)	1.602 (18.165)	−1.476 (4.786)
Living area: rural	Ref (-)	Ref (-)	Ref (-)
Living area: urban	9.125 (5.434)	16.546 (6.275)	4.953 (1.666)
Living area: paris and around	8.380 (10.572)	27.538 (12.527)	6.217 (3.337)
ATM per km^2	0.010 (0.012)	0.009 (0.014)	0.001 (0.004)
Nb of merchants accepting the debit card per inhab.	−0.128 (1.168)	−2.079 (1.358)	−0.171 (0.357)
Number of checking accounts	1.848 (4.708)	−10.008 (5.275)	−5.130 (1.391)
Log(risk)	−5.118 (4.089)	−5.328 (4.790)	−1.325 (1.263)
Distance from bank branch: $<$ 5 mn	*Ref (-)*	–	–
Distance from bank branch: [5 mn; 30 mn]	3.229 (5.690)	–	–
Distance from bank branch: $>$ 30 mn	5.017 (10.694)	-	-
Intercept	35.031 (24.514)	135.102 (27.609)	82.640 (9.159)
ρ	−0.024 (0.077)	−0.024 (0.065)	−0.051 (0.136)
σ	82.1677 (1.757)	105.588 (2.040)	27.932 (0.570)
	$N = 1,151$	$N = 1,383$	$N = 1,383$

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