Precautionary motives in short-term cash management - Evidence from German POS transactions

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Abstract

This paper empirically investigates whether individuals withhold a certain amount of cash for precautionary reasons at the point-of-sale (POS) in order to be able to cover future transactions that might have to be paid for in cash. Such behaviour is costly for consumers because it imposes additional restrictions on their choice of payment instrument at the POS. Based on the analysis of unique payment diary data compiled by the Bundesbank, we find that the probability of a transaction being settled in cash declines significantly as the amount of cash available at one's disposal decreases. This indicates that consumers do indeed refrain from parting with the entire amount of cash in their wallet. Further results suggest that this constraint could be relieved by facilitating access to cash or by promoting card acceptance.

Keywords: payment behaviour, demand for money, cash usage, payment cards, payment diaries

JEL-Classification: D12, E41, E58

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1 Introduction

This empirical analysis investigates whether consumers adopt a precautionary strategy with regard to their short-term cash management and refrain from parting with the entire amount of cash available in their wallet in a payment situation. Understanding the demand for cash is an important topic for central banks as it has an impact on the cost of the payment system, seigniorage revenues and on monetary policy. Moreover, our analysis provides important insights in to the convenience of the German payment system. The necessity to keep a certain amount of cash in reserve is inconvenient for consumers as it imposes restrictions on their choice of payment instrument. By exploring the possible effects of two policy options, our results can be used to guide the design of payment systems more convenient for consumers.

The idea of examining the precautionary motives behind keeping a money reserve goes back to Keynes (1936). In his theory, precautionary reserves can be held in the form of cash or demand deposits and serve to protect against high expenses that might arise in the distant future. This paper looks at the issue from a more short-term perspective: we are interested in those cash reserves which are kept in one's wallet in order to cover any point-of-sale (POS) transactions that may occur before the consumer is able to withdraw any new cash. To be more precise, we will analyse whether the probability of a transaction being settled in cash declines as the amount of cash available in one's wallet decreases. If so, this would imply that individuals withhold cash to cover future transactions.

Whether individuals try to avoid running out of cash has thus far only been documented in the context of consumer withdrawal behaviour (Alvarez and Lippi 2009; Deutsche Bundesbank 2010). To the best of our knowledge, this paper is the first to empirically investigate precautionary motives in cash management, also in the context of payment behaviour. It is related to recent theoretical and simulation studies which work on the assumption that payment behaviour at the POS is dependent on an individual's cash holdings (Bouhdaoui and Bounie 2012; Arango et al. 2013).

We find evidence to suggest that consumers do, in fact, keep a certain amount of cash in reserve, even though it is costly for them to do so. Besides the classic Baumol-Tobin costs of holding cash, it also imposes restrictions on their choice of payment instrument at the POS. We therefore also explore the reasons for this precautionary behaviour and give advice on how the payment system could be improved from a consumer perspective. We focus on two aspects of the German payment system that might have an

influence on whether consumers avoid running out of cash: difficulties in using a payment instrument other than cash and limitations with regard to suitable withdrawal opportunities. In Germany, almost all consumers own one or more payment cards (Deutsche Bundesbank 2013). These cards could be used as a back-up to cover unforeseen outlays in cases where consumers run out of cash, which should eradicate the need to keep a cash reserve. However, cards are far from being universally accepted. For 40% of all POS transactions in 2011 consumers did not have a choice as to how they would like to pay, but were required to pay in cash.[1] This, together with the fact that withdrawals in Germany are not always free of charge and it is not always possible to withdraw cash after each payment transaction, may explain why short-term cash reserves are held. In our analysis, we will test whether a higher card acceptance rate and / or better access to cash would have an influence on the cash saving behaviour and thus make the payment system more consumer friendly.

For our analysis, we use payment diary data collected as part of the Bundesbank's 2011 study on Payment Behaviour. This data has a number of characteristics that make it highly suitable for our analysis: first, it provides detailed information on both the respondents' cash expenditure and withdrawal habits. This enables us to calculate the exact cash balance for every single transaction recorded in the payment diaries. Second, the diary covers consumers' transactions over a one-week period. Thus, we observe more than one transaction for each consumer. This allows us to carry out an important robustness check: we can use individual fixed effects and control for time constant unobserved heterogeneity among consumers. Third, the time dimension in the data allows us to test whether precautionary behaviour in a given payment situation depends on the availability of a cash machine or the possibility of being able to pay by card during a shopping trip.

We find that the decision whether to pay in cash or by card depends significantly on the amount of cash left in one's wallet. While the average probability of paying by cash is 81%, this will drop to around 61% if a consumer were left with just €5 in his wallet after making a transaction. The result shows that consumers avoid parting with the entire amount of cash in their wallet and keep a certain amount in reserve. Furthermore, we find that the precautionary behaviour becomes much weaker when the consumer has the opportunity to withdraw cash after making a transaction or can make frequent use of cards in a payment situation. This suggests that limited access to cash and a low card acceptance rate are both important factors in explaining why individuals keep a certain

[1] Own estimation based on the 2011 study on payment behaviour conducted by the Deutsche Bundesbank. The figure reflects the respondents' subjective perception.

amount of cash in reserve and indicates ways in which the payment system can be made more convenient for consumers.

The rest of the paper is structured as follows: section two briefly reviews the literature related to the precautionary demand for money and clarifies our research question and contribution. Section three specifies our research hypotheses against the background of the German payment system. Section four presents the data and empirical methodology, while section five highlights the main results. We discuss the robustness of our results in section six, before moving on to conclude our findings in section seven.

2 Literature and research question

In his "General Theory of Employment, Interest and Money" (Keynes 1936), Keynes distinguishes between three reasons for holding money: the transaction motive, the precautionary motive, and the speculative motive. Money held under the transaction motive are balances which are needed to carry out planned expenditure. By contrast, precautionary balances are held to ensure that an individual has a certain reserve to cover any unforeseen transactions. The purpose of speculative balances is to be prepared for profitable investment opportunities.

In this paper we deal with the precautionary motive of money demand. According to Keynes, individuals keep precautionary reserves when, on the one hand, there is uncertainty with regard to future expenditure and, on the other hand, there are costs involved in converting invested money into money that can immediately be used for payments (cash and demand deposits). Whalen (1966), Tsiang (1969), and Frenkel and Jovanovic (1980) devised theoretical models for analysing the precautionary demand for money. These theories consider precautionary reserves to be long-term holdings that have the purpose of protecting against any high expenses that might occur in the distant future (e.g. medical costs, accidents, period of unemployment, or ceremonial occasions).

The arguments put forward by Keynes may also hold true in the short term, however. We argue that individuals hedge against unforeseen events, such as having to pay in cash for POS transactions before being able to withdraw cash, by holding short-term cash reserves. Alvarez and Lippi (2009) are the first to incorporate similar precautionary motives into a theoretical model to describe short-term cash management. They relax the standard Baumol-Tobin assumptions of deterministic withdrawal and opportunity costs of cash holdings (Baumol 1952; Tobin 1956) and introduce the possibility of being able to withdraw cash at random times at no cost. Given that individuals often do not know whether they are going to come by a free-of-charge withdrawal opportunity,

they tend to withdraw cash whenever they do happen to come by one, even though their cash balances have not yet reached zero. The amount of cash individuals have in their wallet when making a withdrawal is held for precautionary reasons. Furthermore, Arango et al. (2013) build a model where individuals hold a minimum level of cash reserves because they are not able to perfectly predict the flow of future payments. In this setting, consumers who want to use cash as a principal payment instrument withdraw cash as soon as their cash reserves drop below the lowest transaction amount expected.

Empirical evidence on precautionary motives in short-term cash management can be taken from various surveys on withdrawal and payment behaviour. In these surveys, individuals are asked directly about the amount of cash they usually have in their wallet when making their next withdrawal. According to the Bundesbank's 2011 study on Payment Behaviour, for example, the average withdrawal threshold of German consumers is around €34. Moreover, Arango et al. (2013) use data from these surveys to simulate their model of precautionary cash holdings. The model fits the German data very well and confirms the assumptions that German consumers who want to use cash make precautionary withdrawals when there is uncertainty with regard to future transactions.

In this paper, we present additional evidence which shows that precautionary motives play a significant role in consumers' short-term cash management decisions. In contrast to the studies cited above, we reverse the angle. We do not analyze cash *withdrawal* but cash *spending* behaviour. While previous empirical studies asked: "do individuals bring forward *making withdrawals* in order to avoid running out of cash?", our paper asks: "do individuals *avoid making cash payments* in order to avoid running out of cash?". More precisely, our research question is: "do individuals refrain from spending the entire amount of cash available in their wallet in a payment situation and instead choose to pay by card in order to keep a cash reserve for future transactions which may have to be settled in cash?"

The purpose of our analysis is not so much to give a complete picture of the extent to which individuals keep cash as a reserve. The main focus is rather to analyse whether the need to keep a sufficient cash reserve affects consumers' payment behaviour.[2] Our study thereby adds to a strand of literature that empirically investigates the choice of

[2] To clarify the importance of dinstinguishing between these two research questions, consider, for instance, a consumer who has a general preference for card payments. This consumer's payment behaviour will not be affected by precautionary considerations with regard to his cash reserve as he uses his card whenever possible. Yet, from this result, we cannot infer that he does not keep a certain amount of cash in reserve.

payment instruments at the point of sale (e.g. Boeschoten 1992; Bounie and Francois 2006; Klee 2008; Schuh and Stavins 2010; von Kalckreuth et al. 2011; Wakamori and Welte 2012; von Kalckreuth et al. 2013; Kosse and Jansen 2013). According to these studies, payment behaviour depends on the specific payment situation, the characteristics of the consumer and the advantages offered by the different payment instruments. A shortcoming of these studies is that they look at the issue from a purely static perspective and analyse a consumers' purchases in isolation from each other. We enrich this empirical literature by incorporating a dynamic aspect. We demonstrate that expectations with regard to future transaction and withdrawal opportunities also play an important role when choosing a payment instrument. More precisely, we will analyse whether the probability of a transaction being settled in cash declines as the cash reserve in one's wallet declines. If so, this would suggest that individuals withhold cash for future transactions.

To date, there is virtually no empirical evidence on the relationship between cash at hand and the probability of using cash as a payment instrument. Based on Canadian payment diary data, Arango et al (2011; 2012) report a positive correlation. However, owing to data limitations, the authors use the amount of cash an individual possesses at the beginning of the diary as a proxy for the actual amount of cash the individual has available in any given payment situation. In our paper, we use the Bundesbank's payment diary data. As the German payment diaries contain information on both cash payments and withdrawals, we can calculate the cash flow across all the transactions in the diaries. This enables us to estimate the correlation between the probability of a transaction being settled in cash and the amount of cash left over in the consumer's wallet for any given transaction.

3 Institutional background and hypotheses

In this section we define our research hypotheses. We thereby build on the theoretical and empirical evidence cited above, taking into account the particularities of the German payment system.

According to the theoretical considerations of Keynes (1936), keeping a certain amount of cash in reserve is rational when costs occur for converting deposit money into cash and when uncertainty exists with regard to future transactions. Both conditions are applicable to the German payment system.

Withdrawal costs arise as a result of the fact that it takes time (and money) to get to the nearest ATM or bank counter. On average, a German consumer needs eight minutes to

get from home / work to his usual withdrawal location (von Kalckreuth et al. 2013).[3] Furthermore, consumers have to pay substantial charges (around €4 on average) when they use the ATMs of a bank where they do not hold an account. Thus, even when there is an ATM nearby, it may still be costly to withdraw cash if the cash machine does not belong to the consumer's home bank.

It is also reasonable to assume that consumers are sometimes confronted with unforeseen transaction opportunities. But is this still a valid argument in terms of explaining why consumers keep a certain amount of cash in reserve? Almost all German consumers owned one or more payment cards in 2011 (Deutsche Bundesbank 2013). These cards can act as a back-up to cover unforeseen transaction opportunities and should render the need to keep a cash reserve redundant. This implies, however, that consumers think of cash and cards as perfect alternatives. In fact, there may be payment situations where consumers consider cash to be the only appropriate payment instrument. In the Bundesbank's 2008 study on Payment Behaviour, respondents were asked to evaluate cash and payment cards according to different criteria.[4] The answers show to what extent consumers consider payment cards to be an adequate substitute for cash. In the eyes of the respondents, cash outperforms cards in terms of three important criteria. First, cash is found to be a particular quick and convenient payment instrument.[5] Thus, cards may not be a good alternative to cash in payment situations where time is particularly scarce. Second, respondents appreciate the anonymous nature of cash as a payment instrument. By contrast, card payments are automatically recorded and are associated with the risk of identity theft and card fraud. Thus, cards are an imperfect substitute for cash in payment situations where an individual does not want to reveal personal data. Third, and perhaps most importantly, cash is a universally accepted means of payment, whereas card acceptance is still rather arbitrary in Germany. According to the Bundesbank's payment diary data from 2011, in only 60% of all payment situations is the consumer given the option whether he would like to pay by cash or by card. In other words, in 40% of the payment situations, it was only possible to pay by cash. Some of the smaller retail outlets in Germany, such as bakeries or hairdressers, are not equipped with card payment terminals.[6] Some retailers who do have a card terminal sometimes refuse to accept cards if the transaction value is too

[3] The ATM density is in Germany is around one ATM per 1,000 inhabitants. This figure is slightly above the euro-area average (see http://sdw.ecb.europa.eu/).
[4] See Deutsche Bundesbank (2009).
[5] This perception is corroborated by Klee (2008) who finds that cash payments are, on average, settled ten seconds faster than card payments.
[6] See e.g. EHI (2011) for the payment terminal coverage of German retailers.

small.[7] And there is always the risk of the card terminal or the payment card itself not working properly. So even if customers are willing to use cards in a payment situation, they might not be able to do so. In summary, even though payment cards can theoretically act as a back-up in the case of unforeseen outlays, there are still many payment situations where payment is required in cash.

Building on these arguments, we can formulate the following main hypothesis:

H1: Consumers refrain from parting with the entire amount of cash available in their wallet in a payment situation and keep a certain amount of cash as a reserve. Thus, the probability of a transaction being settled in cash declines as the amount of cash that would be left over in one's wallet after cash payment decreases.

In addition, we will analyse how consumers decide how much cash to keep in reserve. We will examine whether there is a fixed minimum threshold of cash that a consumer wants to have in his wallet, or whether the optimum cash reserve depends purely on the specific payment situation. Our second hypothesis is therefore:

H2: Consumers are guided by a fixed minimum cash reserve threshold. They will opt to pay by card instead of by cash if paying by cash will leave them with less than this minimum threshold.

In a last step, we will examine the motivations for keeping a cash reserve. Is it because consumers fear that they will not be able to find a suitable withdrawal opportunity should they need one or is it because they fear getting into a payment situation where cash is the only payment instrument accepted? We therefore formulate the following two hypotheses:

H3: A consumer is less likely to withhold cash in a payment situation if he can easily withdraw cash before making his next transaction.

H4: A consumer is more likely to withhold cash in a payment situation if he is frequently confronted with payment situations where cash is the only payment instrument accepted.

The results for these two hypotheses can be used to give advice to policy-makers who want to improve the convenience of the payment system for the consumer. The need to keep a certain amount of cash in reserve is inconvenient for consumers as. They are forced to use cards in payment situations where they would have otherwise preferred to pay in cash. The results for H3 and H4 show whether such constraints could be

[7] The reason for this is that they have to pay a fixed minimum charge (around 8 cents) per transaction to the payment system operator and are not allowed to pass on this charge to the customer.

alleviated by promoting free-of-charge withdrawal opportunities and/or card acceptance.

4 Empirical strategy

4.1 Data and sample

Our analysis is based on data collected as part of the Bundesbank's 2011 study on payment behaviour. The study provides a representative sample of the German-speaking population aged 18 years and above living in Germany.[8] The first part of the survey consists of a face-to-face interview on the participants' payment habits and their socio-economic background. After the interview, the participants were asked to keep a payment diary over a one-week period. For each transaction, the respondents are asked to write down the type of location, the transaction amount and the payment instrument used.[9] Furthermore, the diaries contain information on the amount and the time of cash withdrawals which enables us to calculate the exact amount of cash in one's prior to each transaction. The 2011 payment diaries contained 20,130 transactions from a total of 2,098 individuals.

We restricted the sample to transactions of individuals in possession of at least one payment card, i.e. a debit and/or a credit card, (19,348 transactions) as otherwise, a customer would not be able to choose between paying by cash or by card in a payment situation. For this same reason, we considered only transactions where respondents stated that it was possible to pay both in cash and by card (8,730 transactions) and where respondents had enough cash on them to settle the transaction in cash (7,981 transactions). Furthermore, for our main analysis, we considered only those transactions of individuals who kept accurate information on cash flows. We considered information on cash flows to be accurate when the final amount of cash that respondents stated to have on them at the end of the diary recording period corresponded with the final amount of cash that we calculated on the basis of the participant's transactions and withdrawals (+/-50 cents).[10] After deducting those individuals with imprecise cash flow data, we were left with just 36% of the remaining transactions.[11] We also excluded one transaction with a value of €11,000. The final estimation sample consisted of 2,801 transactions from a total of 636 respondents.

[8] For more information on the data see Deutsche Bundesbank (2013).
[9] The diaries do not refer to regularly recurring transactions as these are usually settled by transfer.
[10] For each individual, we calculated the amount of cash available at the beginning of the diary reporting period, minus the sum of all the cash transactions reported in the diary, plus the sum of all cash withdrawals reported in the diaries.
[11] Given the high transaction loss ratio, the robustness checks in section six will also address the possibility of a sampling bias.

4.2 Model, variables, and descriptive statistics

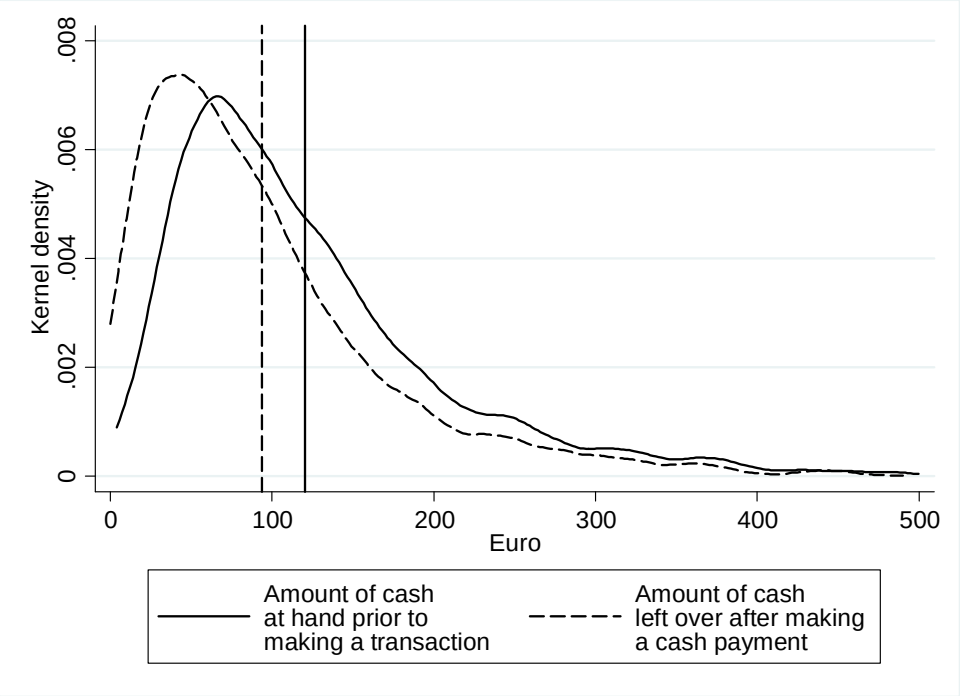
We estimate a probit model at the transaction level, whereby the dependent variable takes the value of one if a transaction is settled in cash and a value of zero if it was settled by another means of payment. In our estimation sample, 81% of the transactions are paid for in cash, which correlates with the share of cash payments in the full 2011 sample.

Our main hypothesis is that consumers refrain from spending the entire amount of cash available in their wallet in a payment situation and opt to pay by card instead (H1). The probability of a transaction being settled in cash should therefore be positively correlated with the amount of cash a consumer would be left with after making a cash payment, henceforth referred to as the *cash reserve*. For each transaction, the *cash reserve* variable is constructed as follows: first, we calculate the amount of cash an individual has in his wallet at the beginning of the transaction, which is the amount at the beginning of the diary recording period minus any subsequent cash expenses plus any subsequent cash withdrawals.[12] We then subtract the amount of the pending transaction. Thus, for transactions that are paid for in cash, the variable contains the true amount of cash after the transaction. For transactions that are paid for by card, the variable gives the fictive amount of cash that would still be in an individual's wallet if he had paid by cash instead.

Figure 1 shows kernel density estimates of the amount of cash at the beginning of a transaction and the amount of cash that would be left over after cash payment (*cash reserve*). On average, individuals enter the retail outlet with a cash balance of around €120 and would leave with a cash balance of around €94 if they paid for all purchases in cash.

[12] We also considered whether a consumer refills his wallet with cash which was kept at home or whether the cash was taken out of his wallet.

Fig. 1 Kernel density estimation of the amount of cash available in one's wallet



Note: The two vertical lines represent the means of the distributions.

Just like in previous empirical works on payment behaviour (e.g. Boeschoten 1992; Bounie and Francois 2006; Klee 2008; Schuh and Stavins 2010; von Kalckreuth et al. 2011; Wakamori and Welte 2012; von Kalckreuth et al. 2013; Kosse and Jansen 2013), this model contains further control variables. In our baseline specification (specification 1), we include several variables to describe the transaction (transaction amount, location, day of the week, month) as well as a number of characteristics describing the individual (age, education, income, sex, marital status, number of household members, community size, nationality, West/ East German household, credit card ownership).

Note that in our specification, the transaction amount is entered twice: (i) indirectly when calculating our main explanatory variable *cash reserve* and (ii) directly as an independent control variable. The reason for this is that the transaction amount affects payment behaviour in two different ways (Whitesell 1989; Arango et al. 2011): (i) it reduces an individual's cash reserve in the case of a cash payment and (ii) it determines the relative ease of cash and card usage. The coefficient of the variable *cash reserve* measures the reduction effect (as it is supposed to) while the coefficient of the control

variable *transaction amount* indicates the net effect of speed differences in cash and card payment.[13]

Estimating the effect of the remaining cash reserve on the probability of using cash in a payment situation could be subject to an endogeneity bias. Both the remaining cash reserve and the decision whether to pay in cash depend on an individual's payment preferences, which are not taken into account in the model. We will come back to this problem in section six.

In order to test H2, H3 and H4, we will start with specification 1 and add different explanatory variables (specifications 2, 3, and 4). H2 states that individuals have a fixed minimum cash reserve threshold in mind when they make a decision whether to withhold a certain amount of cash in a payment situation. By way of an approximation of this threshold for our regression analysis, we take the amount of cash respondents usually have left in their wallet when making a new withdrawal. This amount is available directly from the payment survey questionnaire and indicates the threshold from where individuals usually start refilling their cash reserves. It may also represent the threshold from where individuals start retaining cash in a payment situation. We will analyse whether individuals intensify their precautionary behaviour when their cash reserves risk falling below this threshold. The distribution of the withdrawal thresholds is shown in Figure 2. For the empirical test, we generate an indicator variable which has the value of one if the remaining cash reserve is below an individual's threshold (20% of the sample) and otherwise zero. We add this variable as well as an interaction term between this variable and the remaining cash reserve to specification 1 to arrive at specification 2. If individuals are guided by a fixed minimum cash reserve threshold, the precautionary behaviour is likely to be more intense below the threshold.[14]

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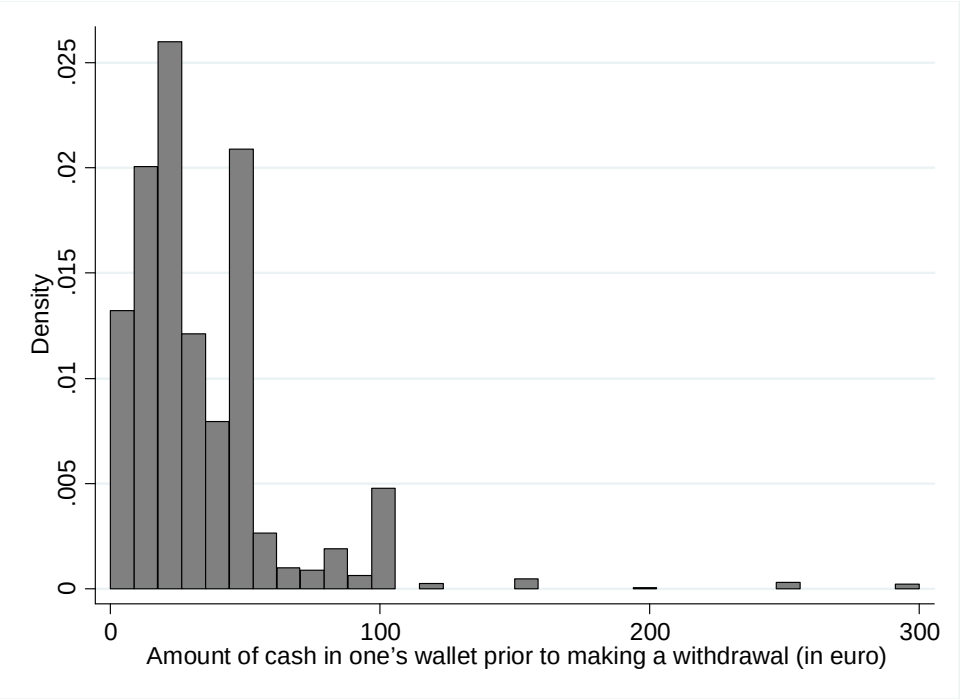
[13] Note that as long as the model contains the *transaction amount* as a control variable, we could also simply use the amount of *cash at the beginning of the transaction* instead of the *cash reserve* left over after making a cash payment as a variable to test our hypotheses. In our specification, the probability of a transaction being settled in cash is given as $P(cash = 1) = \Phi (\beta_1 \text{ cash reserve} + \beta_2 \text{ transaction amount} + \delta' X)$ where Φ denotes the standard normal cumulative distribution function, β_1 and β_2 are coefficients, δ is a vector of coefficients and X is matrix containing additional control variables. Considering the definition of *cash reserve*, we have $P(cash=1) = \Phi (\beta_1(\text{cash at the beginning of the transaction - transaction amount}) + \beta_2 \text{transaction amount} + \delta' X)$ which is the same as $P(cash = 1) = \Phi (\beta_1 \text{ cash at the beginning of the transaction} + (\beta_2 - \beta_1) \text{ transaction amount} + \delta' X)$. Thus, as long as the variable *transaction amount* is included in the model, the coefficients of *cash at the beginning* and *cash reserve* are the same. We have chosen to use *cash reserve*, however, because it is this variable that our hypotheses refer to: do individuals refrain from parting with the entire amount of cash in their wallet in a payment situation and thus base their decision whether to pay in cash in a given payment situation on the amount of cash that they would be left with afterwards.

[14] A probit model allows the marginal effect of a regressor to depend on the value of another regressor, regardless of whether the model contains an interaction term between the two regressors (e.g. Wooldridge 2010). We additionally include interaction terms to enhance the flexibility of the estimation. See Ai and

Fig. 2 Distribution of the amount of cash an individual has in his wallet when making a withdrawal



In H3 and H4, we analyse the influence of two institutional features that might encourage individuals to keep a certain amount of cash in reserve: a lack of adequate withdrawal opportunities and low card acceptance. For this purpose, we test whether the cash reserve elasticity depends on the opportunities to withdraw cash and to use cards during a shopping trip. Again, starting from specification 1, we estimate two additional specifications. In specification 3, we add an indicator variable that assumes the value of one if an individual withdraws money right after making a transaction (around 9% of the transactions) and otherwise zero, as well as an interaction term between this variable and the remaining cash reserve. According to H3, the effect of the remaining cash reserve should be lower for individuals who withdraw money directly after making a transaction.

For specification 4, we generate a further continuous variable which specifies the share of transactions a consumer was forced to settle in cash during the reporting week. The distribution of this variable is shown in Figure 3. We add this variable, as well as an interaction term between this variable and the amount of cash left after a cash payment. According to H4, the effect of the remaining cash reserve should be higher for consumers who make transactions that have to be settled in cash.

Norton (2003) and Greene (2010) for the correct use and interpretation of interaction terms in non-linear models.

Fig. 3 Distribution of the consumers' shares of transactions requiring cash payment

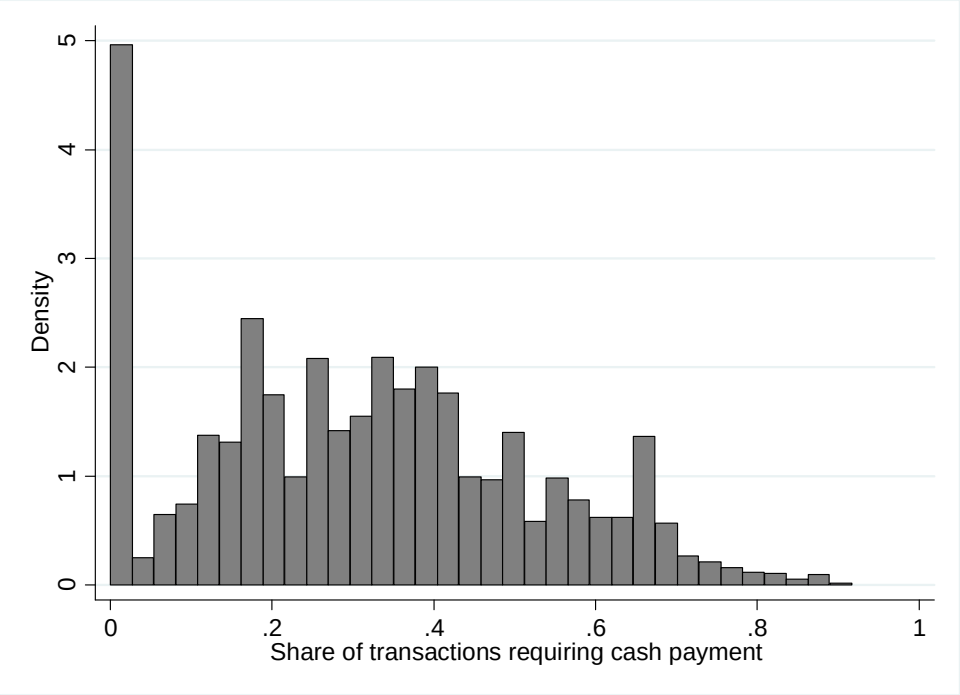


Table 1 provides descriptive statistics on all variables of the analysis. Column one contains the statistics for the estimation sample. Column two additionally presents the same statistics for all observations of the Bundesbank's 2011 study on payment behaviour. A comparison of the two is a useful initial check to examine whether our sample restrictions, especially those on the accuracy of cash flows, could lead to a sampling bias in our estimation results. On the whole, the statistics are largely comparable. The estimation sample shows a slightly higher amount of cash in one's wallet and slightly lower transaction amounts. This is because the estimation sample only contains transactions where the consumer had enough cash at hand to settle the transaction in cash.[15] Furthermore, the estimation sample comprises relatively few payments for coffee and snacks as well as payments to other private individuals as cashless payment was often not possible in these cases. As for the socioeconomic background of the respondents, it is apparent that East German respondents are underrepresented in the estimation sample. This was due to the fact that East German respondents made a greater number of transactions where cashless payment was not possible. Based on this comparison, there is no evidence to suggest that our sample restrictions compromise the validity of our estimation results. Additional robustness checks will be presented in section six.

[15] The standard deviations of the variables measuring the transaction amount and the amount of cash in one's wallet are much lower in the estimation sample, as our sample restrictions remove a couple of outliers.

Table 1 Descriptive statistics

Variables	Estimation sample		Full sample	
	Mean	*SD*	*Mean*	*SD*
Cash payment	0.81		0.81	
Amount of cash prior to making a transaction	120.31	84.43	122.43	200.28
Transaction amount	26.60	22.64	31.68	193.31
Amount of cash left over after cash payment (cash reserve)	93.72	77.52	90.80	248.49
Type of location				
Retail trade for daily needs	0.53		0.42	
Retail trade for longer-term purchases	0.07		0.06	
Petrol station	0.12		0.08	
Chemist	0.05		0.04	
External services	0.03		0.04	
Vending machines	0.03		0.04	
Restaurant	0.05		0.04	
Cafés, pubs, snack bars, fast food restaurants	0.06		0.13	
Leisure activities	0.02		0.03	
Payments to private individuals	0.00		0.03	
Pocket money for children	0.00		0.02	
Miscelaneous / Not specified	0.03		0.07	
Day of the week				
Monday	0.14		0.14	
Tuesday	0.16		0.15	
Wednesday	0.15		0.15	
Thursday	0.15		0.15	
Friday	0.17		0.17	
Saturday	0.16		0.17	
Sunday	0.06		0.08	
Month				
September	0.15		0.17	
October	0.66		0.63	
November	0.19		0.19	
Age	48.00	15.62	47.53	16.90
Education				
No qualification / Not specified	0.01		0.02	
Secondary education	0.76		0.73	
Higher secondary education	0.15		0.14	
University degree	0.09		0.12	

Table 1 continued

Household income				
income < 1,000€	0.05		0.07	
1,000€ ≤ income < 1,500€	0.14		0.13	
1,500€ ≤ income < 2,000€	0.12		0.14	
2,000€ ≤ income < 2,500€	0.15		0.16	
2,500€ ≤ income < 3,000€	0.17		0.14	
3,000€ ≤ income < 3,500€	0.12		0.11	
3,500€ ≤ income < 4,000€	0.07		0.08	
4,000€ ≤ income < 4,500€	0.03		0.04	
4,500€ ≤ income < 5,000€	0.04		0.03	
5,000 ≤ income	0.02		0.03	
Not specified	0.09		0.07	
Male	0.41		0.46	
Marital status				
Single	0.23		0.26	
Married	0.56		0.55	
Widowed	0.08		0.08	
Divorced	0.13		0.11	
Not specified	0.00		0.00	
Non-German citizen	0.06		0.07	
Number of household members	2.34	1.17	2.32	1.17
East German household	0.15		0.20	
Community size				
size < 2,000	0.03		0.05	
2,000 ≤ size < 5,000	0.07		0.09	
5,000 ≤ size < 20,000	0.22		0.23	
20,000 ≤ size < 50,000	0.16		0.18	
50,000 ≤ size < 100,000	0.09		0.09	
100,000 ≤ size < 500,000	0.23		0.19	
size > 500,000	0.19		0.18	
Credit card	0.35		0.37	
Cash reserve below withdrawal threshold	0.20		0.29	
Cash withdrawal after transaction	0.10		0.11	
Share of transactions requiring cash payment	0.31	0.20	0.39	0.25
Number of transactions:	2,801		20,130	
Number of individuals:	636		2,098	

Note: Unweighted data.

5 Results

Table 2 shows the estimation results of the baseline probit model as discussed in section four (specification 1). The table presents average marginal effects and standard errors in parentheses. Standard errors are clustered as transactions that are carried out by the same individual are not independent. The variables describing the cash reserve and the transaction amount are used in logs. For these two variables, the table additionally shows elasticities.

Table 2 Estimation results of probability of cash usage (specification 1)

Variables	Average marginal effect (/ Average Elasticity)	Standard error
Cash reserve (log)	0.0618***	(0.00814)
	(/ 0.102***)	(/ 0.0151)
Transaction amount (log)	-0.122***	(0.0111)
	(/ 0.201***)	(/ 0.0223)
Type of location		
Retail trade for daily needs	Ref.	Ref.
Retail trade for longer-term purchases	-0.0710***	(0.0253)
Petrol station	-0.127***	(0.0254)
Chemist	0.0629**	(0.0292)
External services	0.0248	(0.0333)
Vending machines	-0.175**	(0.0788)
Restaurant	0.0203	(0.0325)
Cafés, pubs, snack bars, fast food restaurants	0.0247	(0.0297)
Leisure activities	-0.0597	(0.0547)
Payments to private individuals	0.0368	(0.105)
Pocket money for children	-0.0499	(0.220)
Miscelaneous / Not specified	-0.283***	(0.0482)
Day of the week		
Monday	Ref.	Ref.
Tuesday	0.0105	(0.0237)
Wednesday	-0.000822	(0.0249)
Thursday	0.0278	(0.0238)
Friday	0.0167	(0.0236)
Saturday	0.0354	(0.0223)
Sunday	0.00932	(0.0329)

Table 2 continued

Month		
September	Ref.	Ref.
October	0.0209	(0.0296)
November	0.000355	(0.0363)
Age	0.00256***	(0.000946)
Education		
No qualification / Not specified	Ref.	Ref.
Secondary education	0.0236	(0.127)
Higher secondary education	-0.00111	(0.131)
University degree	-0.0614	(0.131)
Household income		
income < 1,000€	Ref.	Ref.
1,000€ ≤ income < 1,500€	-0.0503	(0.0586)
1,500€ ≤ income < 2,000€	-0.0584	(0.0555)
2,000€ ≤ income < 2,500€	-0.0517	(0.0565)
2,500€ ≤ income < 3,000€	-0.0676	(0.0601)
3,000€ ≤ income < 3,500€	-0.0380	(0.0571)
3,500€ ≤ income < 4,000€	-0.0135	(0.0596)
4,000€ ≤ income < 4,500€	0.0237	(0.0672)
4,500€ ≤ income < 5,000€	-0.0876	(0.0892)
5,000 ≤ income	-0.0882	(0.0905)
Not specified	0.00349	(0.0598)
Male	-0.00422	(0.0204)
Marital status		
Single	Ref.	Ref.
Married	-0.0157	(0.0348)
Widowed	0.0349	(0.0527)
Divorced	-0.0531	(0.0424)
Non-German citizen	-0.0124	(0.0487)
Number of household members	0.00538	(0.0107)

Table 2 continued

East German household	-0.00309	(0.0261)
Community size		
size < 2,000		
2,000 ≤ size < 5,000	0.00628	(0.0656)
5,000 ≤ size < 20,000	0.0456	(0.0591)
20,000 ≤ size < 50,000	0.0350	(0.0614)
50,000 ≤ size < 100,000	-0.00184	(0.0650)
100,000 ≤ size < 500,000	0.0227	(0.0616)
size > 500,000	0.0437	(0.0612)
Credit card	-0.140***	(0.0251)
Number of transactions:	2.801	
Number of individuals:	636	

Note 1: The table presents the estimation results of a probit model with cash payment (0/1) as a dependent variable. Standard errors are clustered at the individual level.
Note 2: *, **, and *** indicate statistical significance at the ten, five, and one percent level, respectively.

In accordance with our main hypothesis (H1), there is a highly significant positive relationship between the probability of a transaction being settled in cash and the cash reserve left over after making a cash payment. This result implies that consumers do not part with the entire amount of cash in their wallet in a payment situation but keep a certain amount for precautionary reasons. Expressed as an elasticity, a one-percent fall in the remaining cash reserve is correlated with a 0.1 percent greater probability of opting to pay by card instead of by cash.

The sign of the control variables are as expected. Transaction amount and cash usage are negatively correlated with an elasticity of around 0.2. Transactions at petrol stations and vending machines, as well as purchases of longer-term retail products are less likely to be paid in cash than daily purchases. By contrast, transactions made at the chemist's have the highest probability of being settled in cash. As for the individual specific characteristics, there is a strong negative relationship between credit card ownership and cash payment. Furthermore, the probability of cash payment rises with age.

In order to illustrate the precautionary behaviour, Figure 4 presents the predicted probabilities of cash payment as a function of the remaining cash reserve. On average, the probit model predicts a cash payment probability of 82%. If the remaining cash reserve falls to €10 (€5, €1), the cash payment probability drops to 67% (61%, 46%).

Fig. 4 Predicted probabilities of cash payment as a function of the remaining cash reserve

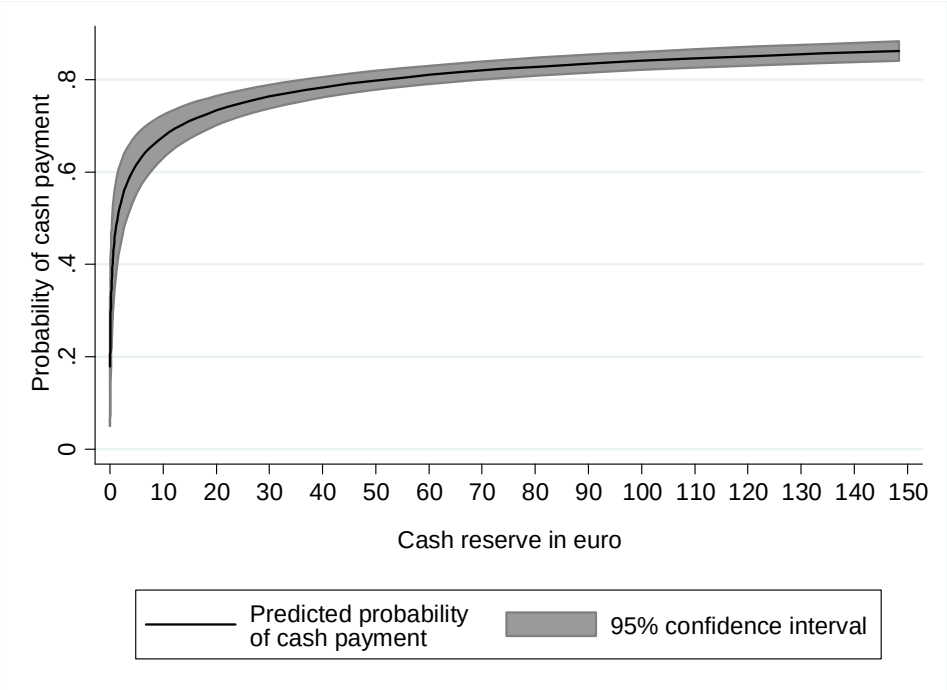


Figure 5 also illustrates the estimated cash reserve elasticities at different levels of the remaining cash reserve. The precautionary behaviour clearly intensifies as the amount of cash in one's wallet approaches zero.

Fig. 5 Cash reserve elasticity of cash payment as a function of the remaining cash reserve

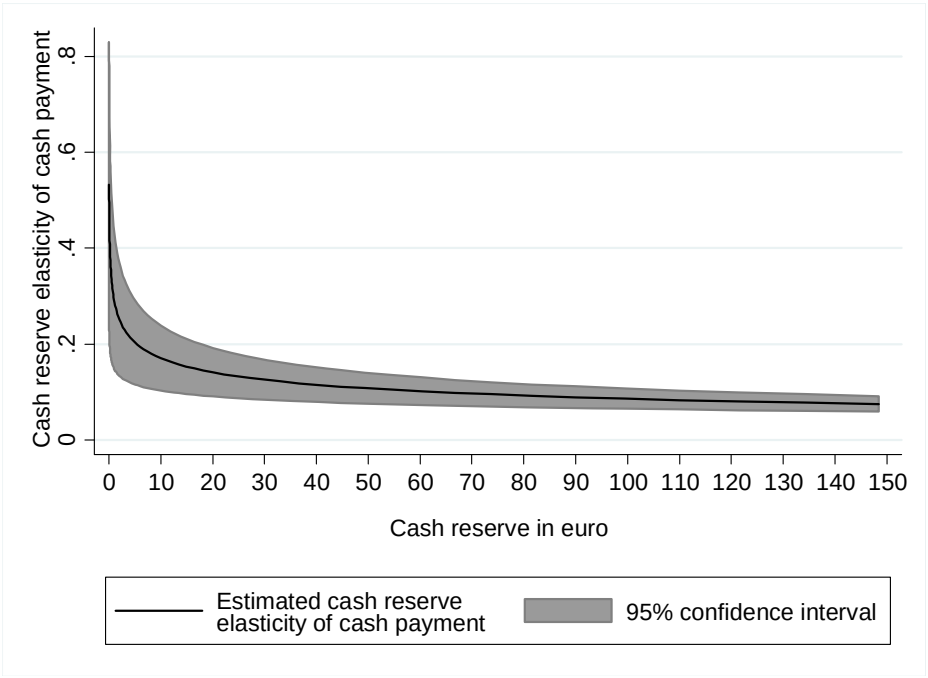


Table 3 shows the results of specifications 2, 3, and 4. For reasons of simplicity, the table presents only the results for the variable *ln (cash reserve)*, the variable that was specifically generated for the respective specification as well as the interaction term between this variable and *ln (cash reserve)*.

The aim of specification 2 is to test whether consumers are guided by a fixed minimum cash reserve threshold. The interaction effect between the consumer's cash reserve and the variable indicating whether this cash reserve is below the consumer's withdrawal threshold is positive but not significant. Thus, we find no evidence for H2.

With specification 3, we want to examine how withdrawal opportunities influence the decision whether to withhold cash. The interaction effect between the consumer's cash reserve and the variable indicating whether the consumer had the opportunity to withdraw cash after the transaction is negative and highly significant. This result consequently speaks in favour of H3. The propensity to save cash seems to be much weaker if the consumer has the opportunity to withdraw cash after making a transaction.

The purpose of specification 4 is to find out to what extent cash reserve behaviour is connected to low card acceptance. The interaction effect between a consumer's remaining cash reserve and the share of transactions that he was required to pay in cash is positive and significant at the ten percent level. This result supports H4. Consumers who often make transactions in outlets where cards are not accepted seem to have a greater probability of withholding cash in a payment situation.

Table 3 Estimation results of the probability of paying by cash (specifications 2, 3 and 4)

Variable	Average marginal effect	Standard error
Specification 2:		
Cash reserve (log)	0.0656***	(0.0115)
Cash reserve below threshold	0.0259	(0.0239)
Cash reserve (log) × cash reserve below threshold	0.00140	(0.0185)
Specification 3:		
Cash reserve (log)	0.0772***	(0.00901)
Cash withdrawal afterwards	0.0697***	(0.0257)
Cash reserve (log) × cash withdrawal afterwards	-0.0730***	(0.0283)

Specification 4:		
Cash reserve (log)	0.0625***	(0.00800)
Share of transactions requiring cash payment	-0.0816*	(0.0433)
Cash reserve (log) × share of transactions requiring cash payment	0.0777*	(0.0433)
Number of transactions:	2,801	
Number of individuals:	636	

Note 1: The table presents the estimation results of different probit models with cash payment (0/1) as a dependent variable. Standard errors are clustered at the individual level. All specifications additionally contain the same control variables as specification 1 in Table 2.
Note 2: The average marginal effects and their standard errors were calculated using the *predictnl* command in Stata. See Norton, Wang, and Ai (2004) for the computation of interaction effects in probit models.
Note 3: *, **, and *** indicate statistical significance at the ten, five, and one percent level, respectively. For the calculation of the significance levels, we assume the distribution of the test statistics to be standard normal.

According to the results of specifications 3 and 4, withdrawal opportunities and expectations regarding card acceptance seem to have a substantial influence on the decision whether to withhold cash in a payment situation. The results of specifications 3 and 4 are illustrated in Figures 6 and 7, respectively. Figure 6 shows the cash reserve elasticities at different levels of the remaining cash reserve for both transactions which are followed by a withdrawal and transactions which are not followed by a withdrawal. The elasticities for transactions that are not followed by a withdrawal are slightly higher than the elasticities for the full estimation sample (c.f. Figure 5). By contrast, for transactions which are followed by a withdrawal, we cannot reject the hypothesis that the elasticity over the entire range of observed cash balances is zero. The precautionary behaviour completely disappears when the individual can withdraw money directly after making a transaction.

Fig. 6 Cash reserve elasticities separated according to subsequent withdrawal behaviour

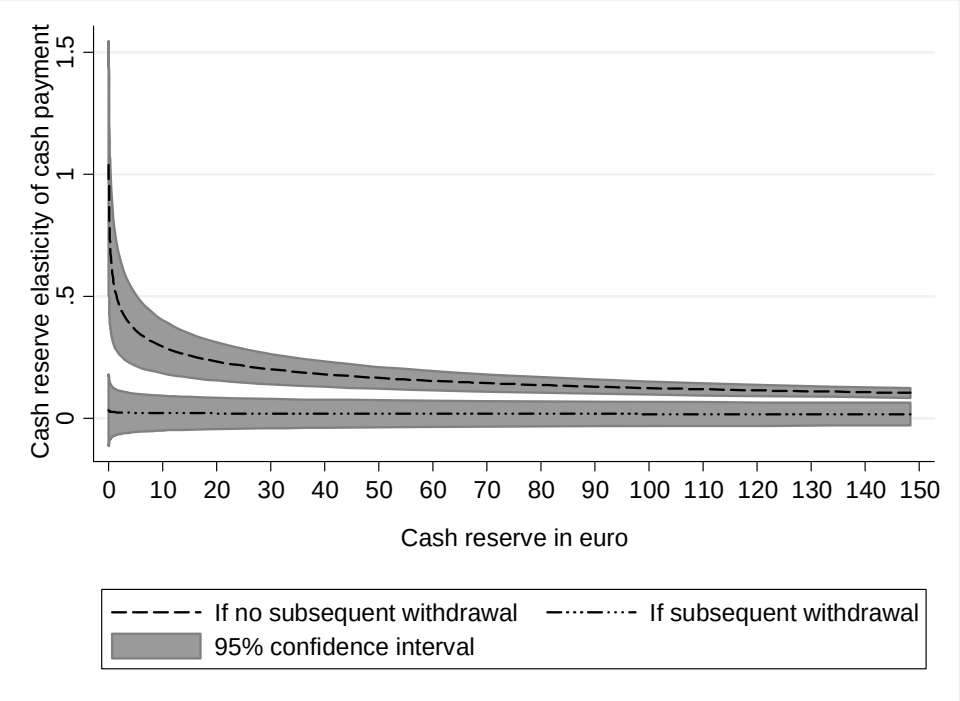
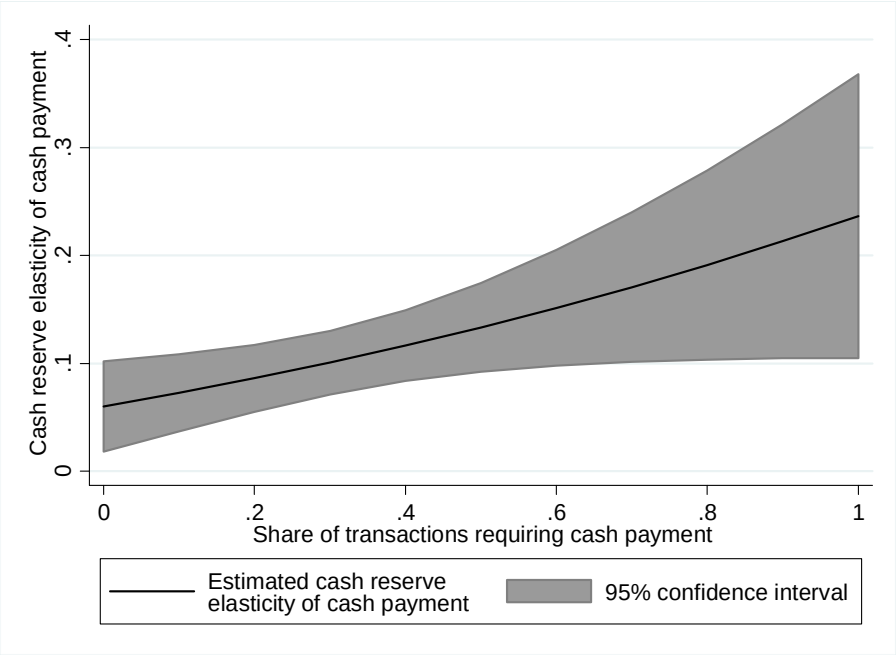


Figure 7 depicts the estimated cash reserve elasticity as a function of the consumers' shares of transactions requiring cash payment. The average cash reserve elasticity is 0.1. By contrast, it would amount to 0.24 if consumers were always forced to pay in cash and 0.05 if consumers were always allowed to pay by card.

Fig. 7 Cash reserve elasticities as a function of a consumer's share of transactions requiring cash payment



6 Robustness checks

To test the validity of our results, we perform several robustness checks. Our tests relate to the selection of our sample (6.1) and the exogeneity of the regressors (6.2).

6.1 Sample selection

For the results presented above, we only use the transactions of individuals who kept accurate information on cash spending and withdrawals (i.e. when the final amount of cash that respondents state to have left over at the end of the diary recording period deviates by less than 50 cents from the final amount of cash calculated by us based on the cash spending and withdrawal data). This leads to a sample reduction of 66%. If individuals with accurate information and individuals with inaccurate information differ in terms of their payment behaviour, the results based on the restricted sample will be biased.

As a robustness check, we re-estimate the baseline probit model using alternative sample restrictions: First, we allow for a larger measurement error in *cash reserve.* In estimation R1a (R1b), we exclude a respondent only if the final amount of cash he states to have at the end of the diary recording period deviates by more than €5 (€10) from the final amount of cash we calculate based on the recorded cash flows. This restriction leads to a sample reduction of only 48% (38%) and the estimation sample should be less selective.[16] In a second check (R1c), we use information on all respondents but only the first transaction. For the first transaction, there is no need for accurate information on subsequent cash flows. The current amount of cash simply corresponds to the amount of cash individuals had at the start of the diary recording period. The marginal effects of the remaining cash reserve of the three estimations are given in Table 4. They are highly similar to those of the main sample (c.f. Table 2, column 1). Thus, we are confident that the results of our analysis are not subject to a sampling bias.

6.2 Endogeneity of the amount of cash in one's wallet

When modelling the choice of payment instruments at the POS, the amount of cash in one's wallet is an endogenous variable. If an individual wants to use cash as payment instrument, he must carry a sufficient amount of cash on him. Thus, a positive relationship between the amount of cash in one's wallet and the frequency of cash payments can occur, even though the amount of cash in one's wallet has no influence on

[16] Allowing for a larger measurement error, the variable *cash reserve* comprises a couple of negative values which cannot be used for estimations in logs. In the case of R1a, we lose three transactions from one individual, in the case of R2b, we lose 11 transactions from two individuals.

payment behaviour. In this section, we address two sources of endogeneity: (i) an individual with a high preference for cash payment has a higher probability of paying in cash and carries more cash on him *in general* (individual specific heterogeneity) and (ii) an individual who plans to use cash in a particular payment situation carries more cash on him *for this particular transaction* (reverse causality).

In order to test whether our estimates are biased owing to individual specific heterogeneity, we make use of the panel structure of our data. We repeat our analysis in a linear framework and compare the results of an individual random effects model with those of an individual fixed effects model. A consistent estimation of the random effects model requires the covariates to be uncorrelated with individual specific unobservables. The fixed effects model can produce consistent estimates even though this condition is violated. Thus, a significant difference between the estimates of the two models suggests that individual specific unobservables are correlated with the covariates which might also lead to a bias in our probit results.

Table 4 Estimation results of different models with cash payment (0/1) as a dependent variable

Specification	Average cash reserve elasticity	Standard error	Number of transactions	Number of individuals
R1a: Probit model allowing for a measurement error in *cash reserve* < €5	0.0946***	0.0119	4,212	937
R1b: Probit model allowing for a measurement error in *cash reserve* < €10	0.0900***	0.0107	4,920	1,077
R1c: Probit model using the first transaction of all individuals	0.0811***	0.0169	1,009	1,009
R2a: Linear probability model with random effects	0.0994***	0.00871	2,801	636
R2b: Linear probability model with fixed effects	0.112***	0.0117	2,801	636
R3a: Probit model using only transactions preceded by a withdrawal	0.0338	0.0287	325	266
R3b: Probit model using only transactions not preceded by a withdrawal	0.114***	0.0169	2,421	615

Note 1: *, **, and *** indicate statistical significance at the ten, five, and one percent level, respectively.
Note 2: The models R1a, R1b, R1c, R2a, R3a and R3b additionally contain the same control variables as specification 1 in Table 2. The model R2b contains all explanatory variables of specification 1 that vary between individuals plus individual fixed effects.

The results for the cash reserve elasticities of cash payment of the two linear models are given in Table 4, lines R2a and R2b. The elasticities are highly comparable across the two linear models and are also very similar to that of the probit model (c.f. Table 2,

column 1). Thus, there is no evidence to suggest that the probit results are biased by individual specific heteroegeneity.

With regard to reverse causality, we carry out the following robustness check: we divide our estimation sample into two groups, depending on whether a transaction is directly preceded by a cash withdrawal or not. If an individual withdraws money directly before making a particular transaction, chances will be high that he is planning on paying for this transaction in cash. In case of reverse causality, the cash reserve elasticity should be higher for transactions which are directly preceded by a cash withdrawal. Lines R3a and R3b of Table 4 present the results of the baseline probit model for the two sub-samples. The elasticities are not higher for transactions preceded by cash withdrawals but close to zero, which we interpret as evidence against inverse causality. Moreover, the absence of cash reserve effects in this subgroup is consistent with our earlier finding that precautionary behaviour is closely related to withdrawal opportunities. If cash reserves have just been replenished, there is no need to keep a precautionary reserve.[17]

7 Conclusions

We have examined whether individuals withhold cash in a payment situation in order to cover future items of expenditure that might require cash payment. To this end, we have analysed whether consumers make their decision whether to settle a payment in cash or by card depending on their remaining cash reserve. According to our regression results, the probability of a transaction being settled in cash significantly declines as the amount of money in one's wallet decreases. The cash reserve elasticity of cash payment is around 0.1 and increases as the amount of cash in one's wallet approaches zero. These results demonstrate that individuals refrain from parting with the entire amount of cash in their wallet and retain a certain amount of cash as a reserve.

On the one hand, this behaviour emphasizes the special role of cash as flexible and reliable payment instrument. Consumers perceive it as a quick, convenient and universal means of payment and try to keep a certain amount of cash available in their wallets. On the other hand, keeping cash for precautionary reasons is costly for consumers. It

[17] As an additional check, we examined transactions that were preceded by an *early* withdrawal. By *early withdrawal*, we understand a withdrawal that takes place before the consumer's cash balance has fallen below the consumer's usual withdrawal threshold. In the case of reverse causality, the cash reserve elasticity should be particularly high for transactions which are preceded by an early withdrawal as the consumer might have brought forward the withdrawal to settle the upcoming transaction in cash. Around half of the withdrawals in our sample were early. If we re-estimate our baseline probit model using only transactions which were preceded by an early withdrawal, the cash elasticity is almost zero and not significant. However, this result is not very reliable due to the small number of early withdrawals (151 transactions).

induces additional cash holding costs and imposes restrictions on the choice of payment instrument.

Whilst exploring the reasons for this precautionary behaviour, we found that the choice of payment instrument becomes completely inelastic to the remaining cash reserve when the individual has the opportunity to withdraw cash after making a transaction. Furthermore, the precautionary behaviour becomes more pronounced if an individual often finds himself in payment situations where cards are not accepted. These results suggest that additional withdrawal opportunities and a higher card acceptance could substantially reduce precautionary cash holdings. Thus, from a consumer perspective, it would be desirable to further improve access to cash by reducing withdrawal fees or by increasing ATM density and to promote card acceptance at the POS. However, in order to make a clear policy recommendation, we would have to compare the costs and benefits that these measures would bring about for all agents in the payment system. This, however, goes beyond the scope of this paper and would be an issue for future research.

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