Journal of Monetary Economics 56 (2009) 222–230

Contents lists available at ScienceDirect

Journal of Monetary Economics

journal homepage: www.elsevier.com/locate/jme

Technological change and the households' demand for currency ☆

Francesco Lippi [a,*], Alessandro Secchi [b]

[a] University of Sassari, EIEF and CEPR[1], Italy
[b] Bank of Italy, Italy

ARTICLE INFO

Article history:
Received 20 September 2007
Received in revised form
5 November 2008
Accepted 6 November 2008
Available online 21 November 2008

JEL classification:
E5

Keywords:
Money demand
Transactions technology
Inventory models

ABSTRACT

It is shown that accounting for technology variations, across households and periods, is important to obtain theoretically consistent estimates of the demand for currency. An inventory model is presented where the withdrawal technology is explicitly modeled. Both the level and the interest rate elasticity of cash holdings depend on the withdrawal technology available to households. Empirical proxies for the household withdrawal technology, based on the diffusion of cash withdrawal points measured at city level, are used to test the model predictions on a panel of Italian household data over the 1993–2004 period.

1. Introduction

Cash usage remains intense. The ratio of cash to GDP for the world economy, between 5% and 8% since the 1950s, displayed an increasing trend over the past 20 years in both high and low income countries (see Fig. 1). Similar patterns emerge from the analysis of individual country data (see Drehmann et al., 2002). Likewise, survey data reported in Table 1 show that despite the strong diffusion of payment and withdrawal instruments that allow households to finance consumption using less cash, such as ATM and POS terminals, the demand for currency by the Italian household hovered around 400 euros over the past 10 years.

This paper takes a step towards understanding the households demand for currency by studying the effects of technical progress in the transactions technology. While technological/financial innovation is often invoked as an important factor affecting money demand, an explicit modeling of the mechanism is rarely found. One problem with the study of money demand is that innovation affects both the extensive and the intensive margin of money demand. The extensive margin gives the proportion of total expenditure that are done using cash. Given this cash expenditure, the household determines the cash inventory to finance it (i.e. the intensive margin). Aggregate data do not allow these two choices to be separately analyzed, and even most microdatabase do not contain information on the household expenditures that are done using cash. A dataset of around 50,000 household level observations, spanning the period 1993–2004, is used. The data contain

☆ We thank the Editor and an anonymous referee for useful comments on a previous version of this paper. We also benefited from the comments of Fernando Alvarez, Giuseppe Bertola, Luigi Guiso, Christian Haefke, Tullio Jappelli, Tom Sargent, Pedro Teles, and seminar participants at the Banca d'Italia, the Bank of Portugal, the SED 2005 Budapest Meeting, the European University Institute, the University of Turin, Rome II "Tor Vergata", LUISS and the 2005 Vienna Macro Workshop. The views are personal and do not involve the responsibility of the institutions with which we are affiliated.

* Tel.: +39 06 4792 4836.

[1] Einaudi Institute for Economics and Finance (EIEF), via Due Macelli 73, 00184 Rome, Italy.

0304-3932/$ - see front matter
doi:10.1016/j.jmoneco.2008.11.001

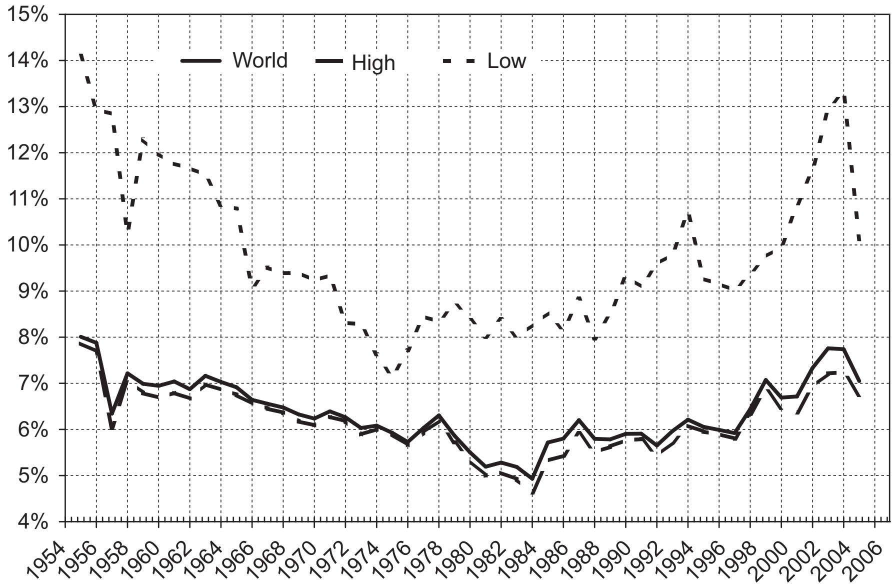

Fig. 1. Currency over GDP: world averages 1954–2006. *Note*: Averages are weighted by the share of a country GDP in the group; whole sample = 98% of world GDP 1995. *Source*: IFS. Shares of world GDP: high income 80.6%, low income 2.9%.

Table 1
Statistics on cash transactions in Italy.

Variable	1993	1995	1998	2000	2002	2004
Full sample						
Fraction with a bank account	0.84	0.84	0.86	0.85	0.86	0.86
Fraction with an ATM card	0.34	0.40	0.51	0.53	0.55	0.56
Households with a bank account						
Average currency holdings						
Without ATM card	460	526	462	460	425	433
	(393)	(388)	(363)	(376)	(352)	(372)
With ATM card	395	444	388	364	359	353
	(345)	(383)	(373)	(332)	(335)	(325)
Cash expenditure per month						
Without ATM card	988	987	847	877	816	847
	(477)	(491)	(467)	(463)	(412)	(424)
With ATM card	1,234	1,262	1,091	1,099	989	948
	(560)	(595)	(644)	(596)	(544)	(548)
Cash expenditure ratio[a]						
Without ATM card	0.91	0.92	0.92	0.92	0.91	0.90
	(0.24)	(0.30)	(0.57)	(0.34)	(0.34)	(0.30)
With ATM card	0.85	0.85	0.84	0.79	0.75	0.69
	(0.27)	(0.27)	(2.02)	(0.34)	(0.36)	(0.33)
Bank branches[b]	0.40	0.45	0.50	0.55	0.58	0.61
	(0.19)	(0.21)	(0.22)	(0.25)	(0.28)	(0.30)
Interest rate[c]	6.10	5.23	2.15	1.16	0.77	0.33
	(0.42)	(0.32)	(0.23)	(0.22)	(0.15)	(0.12)
Full sample observations	8,089	8,135	7,147	8,001	8,011	8,012

Note: Entries are sample averages; standard deviation in parenthesis. Nominal variables are in 2004 euros. *Source*: Bank of Italy—*Survey of Household Income and Wealth*.

[a] Ratio to non-durable expenditures. The denominator excludes imputed rents and non-monetary benefits.

[b] Per thousand residents; observations disaggregated at city level (*source*: Central Credit Register).

[c] Observations disaggregated at provincial level (*source*: Central Credit Register).

information on the household average cash holdings and the value of the expenditure that is done using cash. This allows us to separate the intensive and the extensive margin. The distinction is essential for estimating the transaction elasticity of the money demand. The analysis also casts light on the relation between the money demand interest elasticity and the development of the transactions technology.

Our model modifies the standard inventory theory by introducing a role for the density of bank branches and ATM terminals on agents' cash holding choices. The key difference with respect to the classic Baumol–Tobin framework, where all withdrawals are assumed to be costly, is that in our setup agents are occasionally given the opportunity to withdraw at basically no costs, for example when they meet an ATM terminal while shopping. It is shown that in this economy the level of the money demand and its interest elasticity decrease as the frequency of free withdrawal opportunities increases. Thus, advances in the transaction technology may explain the low interest elasticity that emerges from several empirical studies, see, e.g. Daniels and Murphy (1994) for the US. The theory suggests that the money demand level and curvature varies with the development of the transactions technology. This hypothesis is tested on a panel of Italian households data, first used by Attanasio et al. (2002), which include information on the household access to transaction services (e.g. whether they own an ATM card) and the diffusion of bank branches and ATM terminals. Given the sizeable cross-sectional and time-series variation of the transactions technology faced by households, accounting for these variables is important when estimating the demand for currency.

The paper is organized as follows. The next section presents our model. Section 3 uses the suggestions of the theory to estimate the money demand equation. Section 4 discusses the findings and offers some comments on related literature. A concluding section summarizes the findings.

2. Transactions technology in the inventory model

This section modifies the standard cash inventory model to investigate the relation between the withdrawal technology and the demand for currency. Consider the steady state problem of an agent who uses cash to finance an exogenous stream of expenditure, c. Shopping takes place in one of the several locations of the economy, which may be endowed with a cash dispenser that allows the agent to withdraw cash without incurring a time cost. By contrast, a withdrawal done at a location without cash dispenser entails a cost b, as in the Baumol–Tobin model.

Let $T(M,c)$ be the number of costly withdrawals from the bank that are necessary to finance a consumption flow c when the average money balances are M. It is assumed that T is decreasing in M, so that higher balances allow the agent to finance consumption with less withdrawals, and that T is convex in M, so the minimization problem is well behaved. The money demand solves the minimization problem:

$$\min_M RM + bT(M,c), \tag{1}$$

where R is the net nominal interest rate. The optimal choice of M balances the impact on the cost due to forgone interest with the effect on the cost of withdrawals.

To analyze the effect of technological change in T on the money demand we present two comparative static results, one about the level of money demand and the other about its interest rate elasticity. Both results depend critically on the first order derivative of $T(M)$. The absolute value of the derivative gives the marginal savings in terms of costly trips that the agent reaps by holding one more unit of currency. Let us label $-T'(M)$ as the "marginal withdrawal benefit of money".

Consider two withdrawal technologies, T_i, and the associated money demand schedules, M_i, for $i=1,2$. The first order condition of problem (1) and the assumption that T is convex in M give:

Result 1. *A smaller marginal withdrawal benefit of money, $-T'(M)$, reduces money demand. Formally, if $-T_2'(M)\leqslant -T_1'(M)$ for all M then $M_2\leqslant M_1$ for all $R\geqslant 0$.*

The second result relates the interest rate elasticity to the curvature of the cost function T. In particular, the first order condition of problem (1) and its total differential imply

$$-\frac{R}{M}\frac{\partial M}{\partial R} = 1\bigg/\left(M\frac{T''}{-T'}\right). \tag{2}$$

The expression $-MT''/T'\geqslant 0$ is a measure of the local curvature of the transaction function T. It is also the elasticity of the marginal benefit $-T'$. Thus Eq. (2) says that if the marginal benefit is more sensitive to M, then the money demand is less sensitive to interest rate changes. This yields:

Result 2. *A higher elasticity of the marginal withdrawal benefit reduces the interest elasticity of the money demand. Formally, let M_1 and M_2 denote, respectively, the demand for currency implied by technology T_1 and T_2 when the interest rate is R. If $M_2T_2''(M_{2)}/-T_2'(M_2)\geqslant M_1T_1''(M_1)/-T_1'(M_1)$, then $-(R/M_2)\partial M_2/\partial R\leqslant -(R/M_1)\partial M_1/\partial R$.*

The next subsections use these results to analyze the effect of technological progress in T on money demand for two alternative withdrawal technology specifications.

2.1. Example 1: Baumol–Tobin with free withdrawals

Consider a Baumol–Tobin setup and assume that in every period the agent has p opportunities to withdraw that come for free. Each withdrawal in excess of p costs b. For concreteness, imagine a shopper who passes by a bank branch once every period. This case is represented by a technology T_p with $p=1$. Now suppose that an ATM is installed on the way to her job. This is represented by a new technology with higher p. In general

$$T_p(M,c) = \max\left\{\frac{c}{2M} - p, 0\right\}, \tag{3}$$

where T_p denotes the number of costly withdrawals and the parameter p gives the number of free withdrawals per period.

Setting $p = 0$ in (3) stipulates that all trips are costly, as in the Baumol–Tobin model: $T_0(M,c) = c/2M$.[2] Note that T_0 has a marginal benefit $-T_0'$ with constant elasticity equal to 2, which implies the well known result that the interest elasticity of the money demand is $\frac{1}{2}$. The interpretation of the $p>0$ case is that the agent has p free withdrawals, so that if the total number of withdrawals is $c/(2M)$, then she pays only for the excess of $c/(2M)$ over p. The money demand for a technology with $p \geqslant 0$ is given by

$$M_p(R) = \begin{cases} \sqrt{\dfrac{bc}{2R}} & \text{for } R \geqslant R^* \\ \sqrt{\dfrac{bc}{2R^*}} & \text{for } R < R^* \end{cases} \quad \text{where } R^* \equiv (p)^2 2b/c. \tag{4}$$

When $p = 0$ the forgone interest revenue is small at low values of R, so agents economize on the number of withdrawals and choose a large value of M. Now consider $p>0$. In this case there is no reason to have less than p withdrawals per unit of time, since these are free. Hence, for $R<R^*$ agents choose the same level of money holdings, namely, $M_p(R) = M_p(R^*)$, since they are not paying for any withdrawal but they are subject to a positive forgone interest. Note that over this range the interest elasticity of money demand is zero. Improvements in the particular technology described in (3) produce a money demand that is lower in level and has a smaller interest rate elasticity (in between zero and one-half) because it indeed satisfies the assumptions for results 1 and 2 presented above. To see this, consider two technologies indexed by $0 \leqslant p_1 < p_2$. These technologies satisfy the following three properties:

(i) A greater value of p represents technological progress, because T_p is decreasing in p. Formally $T_{p_2}(M,c) \leqslant T_{p_1}(M,c)$ (with strict inequality for $M < c/(2p_1)$ or, equivalently, $R > R_1^*$).
(ii) A higher value of p decreases the marginal withdrawal benefit of M, $-T_p'$, hence decreases money demand by result 1, at least for some values of M. In particular, $0 = T_{p_2}'(M,c) > T_{p_1}'(M,c)$ over the range: $c/(2p_2) < M < c/(2p_1)$, and equal otherwise.
(iii) A greater value of p increases the curvature of T_p, hence decreases the interest elasticity by result 2. To see this notice that $T_{p_2}(M,c) = g(T_{p_1}(M,c))$ for $g(\tau) = \max\{\tau - (p_2 - p_1), 0\}$. As the transformation is increasing and convex in τ, it follows that technologies indexed by a higher value of p have more curvature.

2.2. Example 2: random coupons for free withdrawals

Consider an economy with two locations: the shopping center and the financial district. Let c be the agent cash-consumption per period, all of which takes place in the shopping center. If the agent cash balance reaches zero, she must walk to the financial district to withdraw more cash, paying the cost b (e.g. the time wasted in this operation). While in the shopping center, however, with probability $p \in (0,1)$ per period the agent receives a storable coupon for a free withdrawal. Think of this as the agent locating an ATM where she can withdraw without paying a fee. It is assumed that she will make use of the coupon (e.g. walk back to this ATM) to refill her balances when they reach zero. Apart from the randomness in the cost of withdrawals (free if a coupon is at hand, costly otherwise) the model is otherwise standard: cash balances follow a saw-tooth pattern and the average money balances (M) and the average withdrawal (W) are related by $W = 2M$, as in the Baumol–Tobin model.[3]

Note that a withdrawal of $2M$ allows the agent to finance consumption for a period of length at least $2M/c$, without having to visit the financial district. The probability that the agent does not receive a free coupon for withdrawal during this period is $(1-p)^{2M/c}$ that, for small p, is approximated by $e^{-(2M/c)p}$. This probability gives the fraction of withdrawals per period $(c/2M)$ which are costly. Hence the transactions technology T_p, which gives the expected number of costly withdrawals for an agent who withdraws $2M$ and consumes c, is

$$T_p(M,c) = \frac{c}{2M} e^{-(2M/c)p}. \tag{5}$$

As for the case discussed in Section 2.1, the technology in (5) has the following features: (i) T_p is decreasing in p, so that higher values of p represent technological progress; (ii) the marginal benefit $-T_p'$ is decreasing in p which, by result 1, implies that the level of money demand decreases as the technology improves; and (iii) the curvature of the cost function, as measured by $(MT''/-T')$, is increasing in p which, by result 2, implies that the interest rate elasticity of money demand

[2] An agent with consumption flow c withdraws $2M$, which last $2M/c$ periods, has average balances M and makes $(c/2M)$ trips to the bank.

[3] Alternatively, and more realistically, one might assume that the coupon cannot be stored, so that it is optimal for the agent to withdraw at the exact time the free withdrawal opportunity materializes. This gives rise to a whole size distribution of withdrawals, where the relationship $W = 2M$ does not hold. See Alvarez and Lippi (2007) for a detailed analysis of this problem.

decreases as the withdrawal technology improves.[4] Compared to the model of the first example, which featured an interest elasticity of either 0 or $\frac{1}{2}$, the interest rate elasticity here is a continuous decreasing function of p that spans the $(0, \frac{1}{2}]$ range.

3. Currency demand and transactions technology

The model suggests that the level and the interest elasticity of the demand for currency depend on the type of withdrawal technology. It predicts that technological improvements, i.e. reductions in the cost of withdrawals, lower the level of the money demand and its interest elasticity (in absolute value).

These hypotheses are evaluated using household level data taken from the *Survey of Household Income and Wealth* (SHIW), a bi-annual survey conducted by the Bank of Italy on a rotating sample of Italian households. The survey collects information on several social and economic characteristics of the household members, such as age, gender, education, employment, income, real and financial wealth, consumption and saving behavior. Each survey is conducted on a sample of about 8,000 households. We focus on the six surveys conducted from 1993 to 2004 because they include a section on the household cash management that contains data on the average amount of cash held by the household and the value of consumption paid with cash. Two additional data sources are the *Italian Central Credit Register* and the *Supervisory Reports to the Bank of Italy*. The former includes information on the interest rate paid by banks on checking accounts disaggregated by year and province (there are 103 provinces). The latter collects the reports that Italian banks file to the Bank of Italy for supervisory reasons and contains information on the supply of various financial services, such as the diffusion of bank branches and of ATM.[5]

Using these data we construct a proxy for the level of the withdrawal technology faced by the household. The proxy is given by the number of bank branches per capita measured at city level (around 300 cities per year). This indicator, whose year averages and standard deviations are reported in Table 1, highlights the steady diffusion of bank services across the territory over the past 15 years as well as its large cross-section dispersion. The indicator is positively correlated with the number of ATM terminals in the time series and across provinces (the correlation coefficient is between 0.75 and 0.94 in each year).[6] There are two caveats, however, in the time-series ATM grows faster than Bank branches: the ratio of the total number of ATM to bank branches is 0.6 in 1993 and 1.2 in 2004. Second, the information we have on bank branches is more detailed than the one we have for ATM: the former is available at the city level, while the latter is only available at the province level.

The estimates presented below are based on a currency demand specification that relates average cash holdings to the value of cash expenditure (both measured at household level), the interest rate paid on deposit accounts and to a proxy for the level of the withdrawal technology. The latter is included both in level and interacted with the interest rate. The currency demand specification also includes demographic controls and year and province dummies that are intended to capture unobserved geographical and time-series factors affecting money demand (e.g. the level of crime).[7]

Following Attanasio et al. (2002) we estimate two separate equations for households with and without ATM card as these two groups are endowed with different withdrawal technologies and we adopt an estimation strategy that allows to control for sample selection (Heckman two-step approach).[8] The inclusion of a measure of withdrawal technology is a crucial difference with respect to these authors.[9]

The results are presented in Table 2 where we report the OLS second stage estimates. The choice to present the OLS coefficients (the so called *direct effect*), instead of the *marginal effect*, is due to our interest in the structural parameters of the inventory problem described in Section 2. Thus the coefficients have the same interpretation of those that would be obtained by applying OLS on a truly random sample of households.[10] The results reported in columns (1)–(3) concern households without ATM card. These are the households for whom our measure of withdrawal technology—the number of bank branches per capita at the city level—is the most appropriate. In column (1) we report the estimates obtained from a standard specification of the money demand. The specification presented in column (2) integrates the technology measure in level. In line with the predictions of the theory, a greater diffusion of bank branches reduces the average currency holdings. The interest rate enters the equation with a negative and statistically significant coefficient—though its magnitude is much smaller than is suggested by the Baumol–Tobin model—and the transaction elasticity is about 0.5, right on top of the square root formula.

[4] Some algebra shows that $(MT''/-T') = 2 + (2pM/c)^2/(2pM/c+1)$ that is increasing in p.

[5] Until the early nineties commercial banks faced restrictions to open new bank branches in other provinces. A gradual process of liberalization has occurred since then, which has led to an increase in the number of bank branches and a reduction of the interest rate differentials across different areas (see Casolaro et al., 2006 for a review of the main developments in the banking industry during the past two decades).

[6] In Italy ATM terminals are owned by banks. About 80% of the ATM terminals are located in the premises of a bank branch; the remaining 20% is not (e.g. is located in airports, shopping malls, etc.).

[7] See Lippi and Secchi (2007) for the results of several alternative specifications.

[8] The choice to present separate equations for households with and without ATM card is supported by the results of a series of formal tests that reject the null hypothesis of equality of the currency holding behavior across the two groups. Details are presented in the online appendix.

[9] See the online appendix for details.

[10] Instead, the marginal effect would be the coefficient of interest if one was interested in predicting the (in sample) conditional mean of M, accounting for both the direct influence of a change in R and the fact that this variation also affects the dependent variable through the Mills ratio (e.g. the participation decision).

Table 2
The demand for currency and withdrawal technology.

	Bank account holders without ATM card			Bank account holders with ATM card		
	(1)	(2)	(3)	(4)	(5)	(6)
log(cash expenditure)	0.467^{**}	0.468^{**}	0.466^{**}	0.339^{**}	0.338^{**}	0.338^{**}
	(0.013)	(0.013)	(0.013)	(0.010)	(0.010)	(0.010)
log(interest rate)	-0.110^{**}	-0.105^{**}	-0.174^{**}	0.036	0.038	0.055
	(0.045)	(0.045)	(0.048)	(0.037)	(0.037)	(0.039)
log(interest rate)·bank branches per capita[a]	–	–	0.104^{**}	–	–	−0.025
			(0.021)			(0.021)
Bank branches per capita[a]	–	-0.130^{**}	-0.134^{**}	–	-0.162^{**}	-0.167^{**}
		(0.034)	(0.034)		(0.031)	(0.032)
Mills ratios						
Bank account	-0.463^{**}	-0.464^{**}	-0.464^{**}	-0.474^{**}	-0.476^{**}	-0.473^{**}
	(0.021)	(0.021)	(0.021)	(0.030)	(0.030)	(0.030)
ATM card	-0.248^{**}	-0.242^{**}	-0.247^{**}	-0.399^{**}	-0.390^{**}	-0.400^{**}
	(0.046)	(0.046)	(0.046)	(0.055)	(0.055)	(0.055)
Province and year dummies	Yes	Yes	Yes	Yes	Yes	
R^2	0.255	0.256	0.257	0.210	0.211	0.211
Sample size	17,339	17,339	17,339	22,512	22,512	22,512

Note: The equations are estimated using Heckman two-step procedure. Bootstrapped standard errors in parenthesis. The regressions also include sex, age, education, and work status of the head of the household, together with living location, number of children, number of adults, and number of income recipients in the household.

[a] Number of bank branches per capita measured at the city level.

Column (3) considers a specification that allows the technology index to affect both the level and the interest elasticity of the demand for currency, as the theory predicts. The estimates confirm the findings of column (2) that a greater diffusion of bank branches reduces the currency demand intercept and that the interest rate (log) level enters the equation with a negative coefficient. The transaction elasticity remains about 0.5. Moreover, the interaction between the interest rate and the diffusion term enters significantly with a positive coefficient. This suggests that the interest elasticity of the demand for currency varies across households, with lower values for households which face a superior technology (a greater diffusion of bank branches). The comparison of columns (1) and (2) with column (3) shows that omitting the interaction term yields an estimate of the *average* interest rate elasticity, which neglects an important layer of heterogeneity. In quantitative terms, the estimates in (3) imply that agents faced with less developed technology, e.g. a diffusion value of 0.1 (the 5th percentile), have an interest elasticity of about −0.2. The interest elasticity falls to −0.1 for the median agent (the median of the diffusion indicator is around 0.5) and is basically nil for the households facing the highest levels of development.

The regressions in columns (4)–(6) concern households who possess an ATM card. We attempt this estimation exercise even though we are aware of the fact that our index for the development of the withdrawal technology—the diffusion of bank branches per capita at the city level—is not the most appropriate measure of diffusion for this type of household.[11] The estimation results should thus be taken with a grain of salt, as they may be subject to a greater amount of measurement error than the ones concerning the households without ATM. In regressions (5) and (6) the level of currency holdings is negatively related to the diffusion of bank branches, with a coefficient magnitude comparable to the one detected for the agents without ATM card. Instead, the interest rate coefficients (both levels and interactions) are not significantly different from zero. In principle, a zero interest elasticity for agents who face a more advanced withdrawal technology can be explained by the models outlined in Section 2. For instance, the Baumol–Tobin model with free withdrawals predicts that the interest rate range over which the demand for currency has a zero interest elasticity expands with technological advances. Finally, the regression indicates a transaction elasticity that is about 0.3.

We conclude this section by exploring the robustness of the estimates for the households without ATM card, those for which our confidence in the indicator of the level of financial technology is high.[12] We begin by assessing whether the estimated coefficients were affected by the choice of the Heckman estimation method. The identification of the currency demand coefficients in the presence of sample endogeneity hinges on the specification of the probit selection equation. In particular, if the first and the second stage estimates have a large set of variables in common, a collinearity problem may occur as the Mills ratio is approximately a linear function of these variables over a wide range of values (see Puhani, 2000). This problem might be particularly relevant in our case since, due to a limited availability of appropriate instruments, the

[11] As mentioned, information on the diffusion of ATM terminals, the natural measure for the ATM card holders, is not available at the city level.

[12] See Lippi and Secchi (2007) for a similar experiment for the other group of households.

Table 3
The demand for currency and withdrawal technology: Robustness.

	Bank account holders without ATM card		
Estimation method	Ordinary least squares (1)	Instrumental variables[a] (2)	Household fixed effects (3)
log(cash expenditure)	0.486**	0.487**	0.394**
	(0.019)	(0.018)	(0.025)
log(interest rate)	−0.181**	−0.241*	−0.330**
	(0.092)	(0.135)	(0.089)
log(interest rate)·bank branches per capita[b]	0.107**	0.103*	0.095**
	(0.036)	(0.062)	(0.046)
Bank branches per capita[b]	−0.107*	−0.153	−0.397**
	(0.058)	(0.128)	(0.135)
Province dummies	Yes	Yes	No
Year dummies	Yes	Yes	Yes
R^2	0.225	0.225	0.081
Sample size	17,339	17,339	7,631

Note: Robust standard errors in parenthesis. The regressions also include sex, age, education, and work status of the head of the household, together with living location, number of children, number of adults, and number of income recipients in the household.

[a] The instruments used for the deposit interest rate and the number of bank branches at the city level are the interest rate lagged value and the number of firms and employees per resident at the city level.

[b] Number of bank branches per capita measured at the city level.

identification hinges on the assumption of normality of the errors and is helped by the exclusion of a variable that measures real financial assets at the household level from the second stage equations. To assess the impact of multicollinearity on the baseline results of column (3) of Table 2 we present a plain OLS estimate of the demand for currency in column (1) of Table 3.[13] The results show that the coefficients on the cash expenditure and the interest rate are not much affected.

We consider next the possibility that some of the regressors are not exogenous with respect to the currency demand shocks. This issue might arise both for the number of bank branches per city and the deposit interest rate at the province level, which might move in response to currency demand shocks that are common to all households of a given city or province. To this end we instrument the interest rates with the previous-year value and the number of bank branches with indicators of industrial activity measured at city level (number of firms and number of employees). The results, reported in column (2) of Table 3, do not show significant differences with respect to the benchmark estimates. The similarity of the OLS and IV estimates suggests a limited relevance of endogeneity problems, an hypothesis confirmed by standard exogeneity tests (not reported).

Finally, column (3) of Table 3 presents a fixed-effect panel estimate on our data, which controls for household-specific unobserved factors. Since the panel dimension is limited to a subset of households, the number of observation for this estimate is smaller. The coefficients of the cash expenditure, the interest rate, and bank branch diffusion are statistically significant and maintain the expected sign. The transaction elasticity is close to the one predicted by the square root formula, in line with all the other specifications. The estimates of the direct (negative) effect of bank branch diffusion on currency holdings and the average interest elasticity (about −0.3) are somewhat larger than the values reported in columns (1) and (2). The coefficient of the interaction term maintains magnitude and statistical significance. This provides further support to the hypothesis that technological advances reduce the average demand for currency and its interest elasticity (in absolute value).[14]

4. Discussion and related literature

The idea that the adoption of advanced withdrawal and payment technologies might have an effect on currency demand is not new. Its empirical relevance has been previously assessed by comparing average cash holdings of less financially developed individuals (i.e. those who only have a bank account) with those of more financially developed part of the population (those who have an ATM or a credit card). Related contributions based on household level data are those of Attanasio et al. (2002) who highlight, based on Italian survey data, which ATM users hold significantly smaller cash balances than non-users. Likewise, Stix (2004) offers evidence concerning Austrian individuals showing that the demand for purse cash is significantly smaller for ATM users. Similar evidence is also reported by Daniels and Murphy (1994) using

[13] The standard errors of the OLS and IV estimates presented in Table 3 take into account the possibility of heteroschedasticity and cross correlation of the shocks within a province in a given year.

[14] Further robustness results are presented in the online appendix.

two large surveys on US households. According to Duca and Whitesell (1995), who follow a cross-sectional approach based on US household survey data, also credit card ownership is associated with lower money holdings. Overall, the evidence consistently indicates that innovations in withdrawal (ATM cards) and payment instruments (credit cards) reduce the level of money balances that agents hold.

The analysis presented in Section 2 confirms the effects of technical progress on average currency holdings. In addition, it shows that interest elasticity of the demand for currency decreases with developments in the withdrawal technology. As far as the level is regarded we have shown that, in line with the theory, both within the class of individuals who have a bank account (but no ATM card) and within the class of those who also have an ATM card, average currency holdings depend on the diffusion of withdrawal points.

The comparison of a standard specification of the currency demand with one that takes into account the level of withdrawal technology (Table 2) illustrates a novel finding of our analysis. While the interest rate elasticity is constant in the standard specification, in our framework it varies with the diffusion of bank branches. Note that the heterogeneity in the diffusion of bank branches is characterized both by a temporal and a geographical dimension. According to our data the average diffusion of bank branches per capita has increased from about 0.4 to 0.6 from 1993 to 2004. As far as the cross-sectional distribution of the diffusion of bank branches is concerned, our data indicate that in 1993 the household associated with the 5th percentile of the distribution of bank branches per capita was characterized by a value of 0.10, while the 95th percentile by a value of 0.70 (respectively, 0 and 1.20 in 2004). This implies that in 1993 the interest rate elasticity ranged between 0.17 and 0.11, while in 2004 the equivalent figures were 0.16 and 0.04. A standard estimate of the money demand equation would neglect this heterogeneity and associate to each household an interest rate elasticity of 0.11 (column (1) of Table 2). A basically zero elasticity was found for agents with an ATM card. This evidence could be due to an imprecise measure of the withdrawal technology available to this class of agents but also, as explained in Section 3, is not necessarily in contradiction with our theory because it is consistent with the theoretical prediction that agents with more developed withdrawal technologies (e.g. ATM card holders) are expected to have a smaller interest elasticity.

The findings concerning the elasticity with respect to the cash expenditure that emerge from the various specifications indicate values that are close to, sometimes a little below, one-half. The estimates are almost identical to those detected on a cross section of Austrian households by Stix (2004), but differ from the near-unit elasticity that emerges by the analysis of long time-series, e.g. Lucas (1988, 2000) and Meltzer (1963), and is predicted by many theoretical models. The issue is of interest in the debate on the optimality of the Friedman rule (e.g. De Fiore and Teles, 2003). A simple reconciliation between the long-run unit elasticity of consumption and the smaller values detected using household data over a short span of years is that the cost of a trip to the bank, b, is linked to the consumption (income) variable in the long-run but less so in the cross section or the short-run). It is reasonable to presume that the cost b is proportional to aggregate wages and consumption in the long run. Formally, assuming a proportionality relation between b and c yields a unit income elasticity if one maintains the reasonable assumption that the transactions technology $T(M,c)$ in problem (1) is homogenous of degree zero in M and c, as in the model economies discussed in Section 2.[15]

5. Concluding remarks

This paper contributes to the quest for accurate quantitative estimates of the parameters that govern the money demand function. It is shown that accounting for the transactions technology available to households is important to identify theoretically consistent estimates of the demand schedule. The analysis is guided by a theoretical framework that shows how advances in the withdrawal technology shift the money demand curve downwards and reduce its interest elasticity. This insight is tested by augmenting a standard money demand equation with a proxy for the withdrawal technology faced by households (the number of per capita bank branches measured at city level) and its interaction with the nominal interest rate paid on deposits. The estimates do not discard the theory. The estimated transaction elasticity of currency is about 0.5. Various estimation exercises show that the interest rate elasticity depends on the withdrawal technology available to households in a way that is consistent with the theory: agents who have access to a superior withdrawal technology (more bank branches or ATM card) have a smaller cash balance and a smaller interest elasticity. Quantitatively, our estimates of the interest rate elasticity range between around -0.2 to almost nil. The quasi-constant cash balance of Italian households shown in Table 1 emerges as the outcome of two opposing forces: lower interest rate, which increase the demand for cash, are countered by improvements in the withdrawal technologies.

Appendix A. Supplementary data

Supplementary data associated with this article can be found in the online version at doi:10.1016/j.jmoneco.2008.11.001.

[15] The proof follows from the first order condition of problem 1: $-R = bT'(M,c)$. The homogeneity of degree zero of $T(M,c)$ implies $bT'(M,c) = b/cT'(M/c,1)$.

References

Alvarez, F., Lippi, F., 2007. Financial innovation and the transactions demand for cash. NBER WP, 13416. Econometrica, in press.

Attanasio, O., Guiso, L., Jappelli, T., 2002. The demand for money, financial innovation and the welfare cost of inflation: an analysis with household data. Journal of Political Economy 110 (2), 318–351.

Casolaro, L., Gambacorta, L., Guiso, L., 2006. Regulation, formal and informal enforcement and the development of the household loan market. Lessons from Italy. In: Bertola, G., Grant, C., Disney, R. (Eds.), The Economics of Consumer Credit: European Experience and Lessons from the US. MIT Press, Boston.

Daniels, K.N., Murphy, N.B., 1994. The impact of technological change on the currency behavior of households: an empirical cross section study. Journal of Money, Credit and Banking 26 (4), 867–874.

De Fiore, F., Teles, P., 2003. The optimal mix of taxes on money, consumption and income. Journal of Monetary Economics 50, 871–887.

Drehmann, M., Goodhart, C., Krueger, M., 2002. The challenges facing currency usage: will the traditional transactions medium be able to resist competition from the new technologies? Economic Policy 34, 193–227.

Duca, J.V., Whitesell, W.C., 1995. Credit cards and money demand: a cross-sectional study. Journal of Money, Credit and Banking 27 (2), 604–623.

Lippi, F., Secchi, A., 2007. Technological innovation and the transactions demand for cash. CEPR Discussion Paper, 6023.

Lucas Jr., R.E., 1988. Money demand in the United States: a quantitative review. Carnegie-Rochester Conference Series on Public Policy 29, 137–168.

Lucas Jr., R.E., 2000. Inflation and welfare. Econometrica 68 (2), 247–274.

Meltzer, A.H., 1963. The demand for money: the evidence from the time series. Journal of Political Economy 71, 219–246.

Puhani, P., 2000. The Heckman correction for sample selection and its critique. Journal of Economic Surveys 14 (1), 53–68.

Stix, H., 2004. How do debit cards affect cash demand? Survey data evidence. Empirica 31, 93–115.