

Whither Loose Change? The Diminishing Demand for Small Denomination Currency

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Abstract

While payment card usage has increased dramatically, the stock of outstanding currency has not declined as rapidly. We analyze changes in cash demand for 13 advanced economies from 1988 to 2003 by separating cash into three denomination categories to disentangle its store of wealth and payment functions. Defining denominations commonly dispensed by ATMs as the “medium” category, we show that demand for small denomination currency decreases with greater debit card usage and with greater retail market consolidation. In contrast, the demand for high denomination notes decreases when interest rates rise, but is generally unaffected by changes in debit card usage.

Key words: payment networks, money demand, consumer choice, technology adoption.

JEL Classifications: D23, E41, G21

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*“Except for the smallest of transactions, money will no longer be a physical thing”
(Forbes 1967 as cited in Flannery 1996)*
“The use of cash and currency will drop drastically...” (Flannery and Jaffee 1973).
“Cash is dirty, inefficient—and obsolete” (Gleick 1996)
“The end of the cash era” (The Economist 2007, cover page).

1. Introduction

While many observers have predicted the replacement of cash for decades, cash holdings remain significant and show few signs of decline in the aggregate. During the last fifteen years, retail electronic payments have grown rapidly in most advanced countries. More recently, many traditionally cash-only establishments such as fast-food restaurants, vending machine operators, and taxis have started to accept cash alternatives resulting in greater downward pressure for transactional cash demand. If there are more merchants accepting cash alternatives and more consumers using them, why is the stock of cash still so high? A significant part of the answer is that cash is not solely used as a means of payment.

In this article, we are primarily interested in answering the following question. Given greater usage of cash alternatives, are households and businesses holding less cash *to make and accept payments*? We disentangle cash’s transactional role from its store of wealth role by categorizing currency into different denomination classes—small, medium, and large. We find evidence that greater usage of debit cards indeed reduces the transactional demand for cash—most notably the demand for smaller denomination currency notes and coins. In addition, we find that greater consolidation in the retail industry also contributes to lower transactional demand for cash, suggesting that larger merchants may be better able to absorb the fixed costs of accepting electronic payments.

This question is of interest to economists and policymakers for several reasons. Most directly, greater usage of cash substitutes affects how much cash the central bank should supply and also influences the income and interest rate elasticities of money demand. The implications of a possible reduction in currency demand for monetary policy has been an active area of economic research (Alvarez and Lippi 2007; Chakravorti 2006; Freedman 2000; Friedman 1999;

Goodhart 2000; Kroszner 2003; Woodford 2000). Moreover, some economists have suggested that social welfare would improve if fewer cash transactions took place (De Grauwe, Buyst, and Rinaldi 2000; Van Hove 2004). Finally, there has been considerable debate among economists regarding the role of financial incentives on the adoption of electronic payments and its impact on the demand for paper-based payment instruments (Chakravorti and McHugh 2002; Humphrey, Pulley, and Vesala 1996; Markose and Loke 2002).

We discuss payment trends in thirteen OECD countries—Austria, Belgium, Canada, Finland, France, Germany, Italy, Japan, the Netherlands, Sweden, Switzerland, the United Kingdom, and the United States—from 1988 to 2003. We find that in most countries, debit card usage has increased significantly. However, the aggregate demand for cash has not fallen drastically with widespread adoption of non-cash payment instruments. Unlike other payment instruments, cash serves as a universally accessible store of wealth in addition to being a payment medium. Thus, any analysis of the impact of cash alternatives must first disentangle the two competing functions of cash. Furthermore, in contrast to payment cards, cash transactions are more difficult to trace to the transactors because it can be used multiple times without third-party intervention. Consequently, cash will continue to be attractive for facilitating illicit transactions, as well as for storing ill-gotten (or, at least, untaxed) wealth.

Our analysis differs from the existing literature in a number of ways. First, we decompose cash demand into three currency denomination categories to better identify the transactional motive for cash holdings. Denominations larger than those commonly dispensed by a country's ATMs are posited to be better suited for store of value purposes. Denominations less than those dispensed from ATMs are required to make change for purchasers that obtained currency from ATMs. We argue that since change is given only in the case of cash transactions, the effects of substitution towards electronic payment instruments are reflected primarily in the demand for these small denomination notes and coins. If cash is not used to transact, the demand

for change and consequently the demand for small denomination currency both decrease. Second, we employ different econometric techniques than those commonly used in this literature to address strong serial correlation that is present in annual cross-country payments data. Finally, our data covers both the time of rapid growth and subsequent saturation in debit card usage in almost all countries in the sample. That is, unlike many of the previous studies, we are able to analyze the effect of accelerating and decelerating changes in debit card usage on cash demand.

We find that the effects of increased usage of debit cards are indeed confined to demand for small denomination currency and coins. Both debit card terminal proliferation and financial institution branch infrastructure significantly affect the demand for *small* denomination currency, whereas the short-term interest rate has little effect. Because financial institutions are the main distributors of small (and large) denomination notes and coins, more extensive branch networks are associated with greater demand for small (and large) denomination currency.

In contrast, the demand for larger denomination notes is affected by the short-term interest rate, but not by the adoption of point-of-sale (POS) debit card terminals. Moreover, there is some evidence that greater adoption of ATMs has, on net, reduced the demand for ATM-dispensed notes. We also find that the share of small merchants in the economy (as proxied by the share of the self-employed) is associated with stronger currency demand. However, this effect is primarily observed through demand for small denomination currency, suggesting that high fixed costs of installing electronic payments terminals and not illicit activity influence cash demand by small merchants.

This paper is organized as follows. In section 2, we discuss payment trends across the countries in our sample. In section 3, we review the literature that analyzes the impact of electronic payment alternatives on cash. In section 4, we focus on the relationship between debit

card usage and changes in the stock of cash, broken by denomination categories. We offer some concluding remarks in section 5.

2. Cross-Country Payment Trend Comparisons

While there are major differences in banking and regulatory structures, as well as in cultural attitudes toward payments between countries in our sample, certain common payment trends exist. Figure 1 depicts one such common trend – the growth in debit card usage during the 1990s. In 1990, all countries except for Finland and France had fewer than 10 debit card transactions per person per year. By 2003, the average number of transactions approached 50, with 5 out of 13 countries recording more than 70 debit card transactions per capita. This monotonic trend suggests that the net benefits of using debit cards have increased vis-à-vis other payment instruments for both consumers and merchants (assuming that the total number of transactions is growing at a slower rate than transactions executed with debit cards).

Another trend is the rapid growth of electronic payments generally. As shown in Table 1, even in countries with a historically high share of check transactions (e.g. the United States, France, and Canada), electronic payments accounted for a vast majority of all non-cash payments in 2005.¹ Furthermore, as also reported in Table 1, non-cash transactions have increased between 2001 and 2005 for all countries in our sample, suggesting a reduction in cash transactions over time within a country.

However, the growing acceptance of cash substitutes has not necessarily resulted in an offsetting reduction in the total stock of currency outstanding. Two measures to compare currency in circulation across countries are cash holdings per capita and the ratio of cash outstanding to GDP. Both of these metrics show substantial cross-country heterogeneity that does not disappear over time. Looking at the opposite ends of the spectrum, the 1988 per capita currency holdings in the UK amounted to \$529, while those in Japan were \$2,296. The

corresponding figures in 2003 (measured in 1988 prices) were \$671 and \$5,292. The currency-to-GDP ratio in the UK changed little over this period, going from 3.5 percent in 1998 to 3.4 percent in 2003. In contrast, this ratio for Japan rose from 9.2 percent to 16.3 percent over the same period fueled, in part, by the extremely low or negative inflation environment. It is worth noting that these aggregate measures are unable to distinguish between cash's store of value and payment functions.

3. Literature Review

The theoretical literature on money demand is quite large.² Many papers extend the Baumol (1952)-Tobin (1956) model where interest rates, income, and the acquisition costs of cash determine the supply of money. Payment practices and transactions costs are fundamental features of these models.³

This article best fits in the empirical literature that investigates changes in cash demand resulting from the adoption of new payment infrastructure. Boeschoten (1992, p.148) found that adoption of debitable accounts and guaranteed checks were responsible for 40 percent of the fall in currency ratio between 1965 and 1975 in the Netherlands. However, this trend reversed from 1975 to 1990 indicating an increased role for banknotes as a store of value. Humphrey, Pulley, and Vesala (1996) (henceforth HPV) estimated a system of demand equations for five payment instruments (check, electronic or paper giro, credit card, and debit card) for 14 countries between 1987 and 1993. Both POS terminals and ATMs were strongly positively related to debit card usage suggesting utilization of similar infrastructure. However, HPV found that all payment instruments *except* for debit cards substitute for cash.

These and most other studies focused on the aggregate currency demand. There are two main problems with using aggregates: measurement and the inability to differentiate between competing uses of currency. In particular, substantial foreign demand for some currencies makes

it difficult to consider the aggregate currency stock as representative of domestic transactions that could be influenced by domestic payments infrastructure. Some recent studies attempt to quantify the potential magnitude of this mismeasurement. For instance, about 60% of U.S. dollars are estimated to be in circulation outside of the United States (U.S. Department of Treasury, 2003).⁴ A similar figure for Deutsche mark prior to the introduction of the Euro was 40 percent (Seitz 1995). Large amounts of Swiss francs are believed to be either held outside of Switzerland or kept in safe deposit boxes inside the country (Fischer, Köhler, and Seitz 2004). With respect to illegal uses of cash, Rogoff (1998) states that between 70 to 80 percent of OECD currency stock is either held by the domestic underground economy or in developing countries.

Since most foreign (and illegal) demand is believed to be held in large denomination currency, disaggregating cash stocks helps with measurement. Doing so also helps to isolate the domestic transactional demand for currency. This is the approach followed by Drehmann, Goodhart, and Krueger (2002) (henceforth DGK) who divide currency into large and small bills, using 50 British pounds as the cutoff line. While DGK get significant estimates for the effects of macro variables, they do not get statistically measurable results for their payment infrastructure or crime variables.

An alternative approach to identifying the impact of debit cards on cash usage is to survey individuals and their payment habits. While surveys are usually limited in scope and time, these studies may help to explain cash demand given a set of payment alternatives from a microeconomic aspect that is not present in aggregate studies of money demand. For Austria, Stix (2003) finds that individuals that frequently make purchases with debit cards hold on average 20 percent less cash in their wallets and those that frequent ATMs hold 18 percent less cash in their wallets. For France, Bounie and François (2006) find that transaction size, type of good purchased and the type of establishment where the purchase is made are key factors for the consumer choice of a payment instrument.⁵

4. Debit Cards and Cash Substitution: Empirical Analysis

A. Data sample and measure of money demand

In this section, we study the impact on the cash-to-GDP ratio resulting from changes in payments infrastructure, merchant size distribution and the opportunity cost of holding cash. We assume that central banks provide an elastic supply of currency. About half of the countries in our sample – Austria, Belgium, Finland, France, Germany, Italy, and the Netherlands – had their own currencies until 2002 when the Euro was introduced. The rest of the countries – Canada, Japan, Sweden, Switzerland, the United Kingdom, and the United States – maintained their own national currencies throughout the sample period. Initially, we consider the total stock of cash outstanding for each country, but later we segment cash into large, medium and small denomination classes to isolate cash's payment function.

We measure money demand for each currency by its ratio of stock of currency outstanding to GDP. In the aggregate, this ratio was decreasing for most countries throughout the 1970's and much of the 1980's. However, it flattened out since then reflecting, in part, successful stabilization of inflation. A number of geopolitical shocks that occurred since 1988 had a measurable effect on demand for certain currencies. In particular, the unification of Germany and disintegration of Yugoslavia resulted in higher demand for Deutsche marks, while the collapse of the Soviet Union greatly increased the demand for U.S. dollars (Fisher, Kohler, and Seitz 2004; U.S. Department of Treasury 2003). In all, the decade of the nineties and the early part of the 21st century (for non-Euro countries) are best characterized by stable currency-GDP ratios.

The currency-to-GDP ratio is a convenient metric of money demand. First, it has a simple theoretical interpretation as the inverse of money velocity. Second, normalization by GDP allows us to analyze developments in multiple countries without worrying about exchange

rate movements.⁶ The ratio is also likely to be stationary, although the short time dimension of our data does not allow us to take advantage of this time series property. Our definition of currency includes the outstanding stock of notes and coins. For euro countries, we only consider the period from 1988 to 1999, which eliminates the last two pre-Euro years in which currency stocks (particularly those of large-denomination notes) started to decline in anticipation of the regime switch. For the other countries, the sample period is from 1988 to 2003.⁷

B. Measure of non-cash payments infrastructure

We use point-of-sale debit terminals to measure the adoption of debit card infrastructure and proxy for debit card usage.⁸ Historically, ownership of debit cards was a necessary but far from a sufficient condition to ensure their widespread usage. Consumers, for the most part unknowingly, added debit cards to their wallets in the 1980s because they were mainly seen as devices to access cash and make deposits at automated teller machines (ATMs). However, they were unable to use those cards to make purchases until merchants adopted POS debit terminals. The installation of debit card terminals by merchants was the critical step that led to the explosive growth in debit card transactions.⁹

In Figure 2, we provide cross-country snapshots of the relationship between currency-to-GDP ratio and the number of debit terminals per 1,000 residents in 1991 and 1999. In a given year, countries with a high prevalence of debit card terminals tend to have lower currency-to-GDP ratios suggesting a strong cross-sectional substitution pattern. However, although nearly every country experienced substantial growth in debit card infrastructure during this decade, it was rarely accompanied by a corresponding decline in that country's aggregate currency ratio.

Unfortunately, we lack satisfactory data for an important non-cash payment instrument – credit cards. Data on credit card infrastructure has not been consistently gathered or disseminated by the countries in our sample. Moreover, in contrast with debit cards, credit cards can be processed without dedicated point of sale terminals (e.g. using paper slips), making

relevant infrastructure more difficult to measure. The number of merchants that accept credit cards could be an alternative proxy of the infrastructure, but such cross-country time series data are not publicly available.

Nevertheless, several salient facts about credit card use allow us to hazard an estimate of their likely effect on cash demand. In most European countries in our sample, widespread debit card infrastructure and usage preceded that for credit cards. The subsequent development of credit card infrastructure leveraged the existing debit card networks. Consequently, the number of merchants accepting both debit and credit cards (what we would like to measure) is likely strongly positively correlated with the number of merchants accepting debit cards (what we are able to proxy for by using number of POS terminals) in the bulk of our sample. In this case, the omission of credit card infrastructure only makes it more difficult to find any relationship between debit card usage and cash demand.

This statistical argument works best if credit cards are used primarily for transaction purposes. In this case, credit and debit cards are close substitutes in the sense that both of them replace cash, and capturing the infrastructure for just one instrument is sufficient. This appears to be an accurate description of credit card usage in much of Europe. There, consumers that initially switched to electronic payments through debit cards likely responded to availability of credit transactions by substituting credit for debit, and not cash. Moreover, in some countries in our sample (e.g. Finland and the Netherlands), credit cards are seldom used for domestic transactions by their residents, which also makes their omission unlikely to affect the results.

The U.S. experience has been markedly different, as credit card adoption occurred well before debit cards. By not capturing credit card infrastructure, we are likely overstating the effect of debit cards on cash demand in the United States, especially given that many establishments started to accept credit cards before PIN-based debit cards. However, the extent of this bias may be limited by the fact that credit cards play a significant role in uncollateralized

borrowing in the United States and thus their acceptance is not as strongly tied to cash displacement.

C. Econometric model

We will econometrically test a money demand equation where the demand for money is a function of alternate payment infrastructure, cash infrastructure, proportion of small merchants, and the opportunity cost of money. We use the following econometric specification:

$$\begin{aligned} (\text{Currency}/\text{GDP})_{it} = & \alpha + \beta_1 \text{Debit Card Terminals}_{it} + \beta_2 \text{ATMs}_{it} + \beta_3 \text{Bank Branches}_{it} \quad (1) \\ & + \beta_4 \text{Share of Self-Employed}_{it} + \beta_5 \text{STIR}_{it} + \varepsilon_{it} \end{aligned}$$

All variables in (1) are in logarithms with subscripts i and t indicating, respectively, an observation in country i in year t . The number of ATMs and bank branches are expressed in per capita terms, while the number of point-of-sale debit card terminals is defined in units per 1,000 residents. We use the IMF *International Financial Statistics* for the share of self-employed and the short-term interest rate (STIR). All other variables are from the Red Book published by the Bank for International Settlements or the Blue Book published by the European Central Bank.¹⁰

The vector of explanatory variables is fairly parsimonious, necessitated by a relatively small dataset and the econometric design that relies on fixed effects estimation. The standard money demand variables that capture shoe-leather and opportunity costs of cash are complemented with several measures of competing payment instruments.

For cash infrastructure (or shoe-leather cost factors), we use the number of ATMs and the number of bank branches per capita. ATMs are a predominant source of cash in all the countries that we study, but the relationship between cash usage and ATMs is theoretically ambiguous. Greater number of ATMs potentially increases the velocity of cash as consumers can access cash more easily. Hence, more ATMs could imply lower currency stocks. On the other hand, greater access to ATMs may reduce the cost of cash vis-à-vis other payment instruments, resulting in greater cash usage.

In a similar vein, we use the number of branches of financial institutions as a measure for cash access, especially for non-ATM dispensed notes and coins. While payers may not mind withdrawing notes of only certain denominations, receivers of cash need to have different denominations on hand to make change. As a result, branches of financial institutions play a key role in disbursing currency of varying denominations to consumers and especially merchants. As in the case of the ATMs, a more extensive branching network may either lower day-to-day cash holdings by merchants (i.e. increase velocity) or increase overall cash holdings through filling a greater number of bank vaults.

The share of self-employed in total employment serves as a proxy for the proportion of small merchants in an economy. The cost of facilitating debit card transactions depends, in part, on merchant size and transaction volume. In particular, smaller merchants would be more reluctant to invest in debit card terminals because their transaction volume may not recover the fixed cost. This is especially the case if such merchants continue to accept cash and incur cash handling costs. Thus, to capture the extent to which merchants can rely on economies of scale in debit card terminal acquisition, we look at the country- and time-specific share of small merchants, as approximated by the share of the self-employed in total employment. We report these ratios for 1999 in Table 2. Note that Italy, Austria, and Japan are near the bottom in debit card transactions and are the top three in terms of self-employed shares.

An additional reason to expect a positive relationship between cash demand and the share of self-employed in the economy is that a more atomistic employment structure may also be associated with lower levels of tax compliance and consequently greater reliance on cash in transactions.¹¹ The second column of Table 2 lists the size of shadow economies for the countries in our sample, as estimated in Schneider (2006). A simple comparison of the two columns in Table 2 suggests a positive association between the self-employed share and shadow

economy size ($\rho=0.5$). Finally, the opportunity cost of holding cash is measured by the short-term nominal interest rate.

D. Results for the aggregate measure of currency-to-GDP ratio

In Table 3, we report results for a number of different econometric approaches to estimating equation (1) for the aggregate measure of money demand. Since all of the explanatory variables reflect domestic conditions, we attempt to reduce measurement error by restricting the sample to countries that do not have substantial foreign demand for their currency. Although we try to account for the foreign component of demand for the U.S. dollars and the Deutsche marks (see Data Appendix), these adjustments may be rather imperfect. Consequently, the residual foreign demand in the dependent variable would obscure the relationship.¹² In addition to the variables described above, we add a Y2K dummy to capture any increase in currency stock resulting from the Y2K concerns in 1999.

In the first column, we report our results using a pooled OLS regression, which treats cross- and within-country effects as interchangeable. We find that a 10 percent increase in the number of debit card terminals per capita (which is a much lower rate of growth than that realized, on average, in our sample countries) results in a 1.2 percent decrease in the currency-to-GDP ratio. We also find that the number of bank branches positively affects the demand for currency, as does the share of self-employed. As expected, the short-term interest rate is negatively related to cash holdings. Interestingly, the pooled OLS results suggest that increase in ATMs reduces consumer cash holdings.

The second column reports the results of estimation with country fixed effects (FE). This allows us to account for substantial serial correlation within individual countries. It also focuses attention on whether within-country changes in the explanatory variables affect country-specific changes in currency demand. While the FE point estimates are significantly lower, the effects of

debit terminals, bank branches, self-employed ratio, and short-term interest rates remain statistically significant. However, there is no measurable effect of ATMs in the FE specification.

The fixed effects provide a remedy for within-country serial correlation only if country-specific effects are constant over time (Petersen 2007). A direct inspection of the residuals from the FE regression suggests that this is not the case. Consequently, column (3) reports clustered standard errors (Rogers 1993), which allow an arbitrary temporal dependency pattern within each country. Making this adjustment substantially reduces the statistical significance of the effect of debit card terminals, and eliminates the significance of self-employment altogether.¹³

In sum, the results of fixed effects estimation differ substantially from those of pooled OLS regressions, particularly if necessary serial correlation adjustments are made. Only the short-term interest rates – the cornerstone of money demand models – retain strong statistical significance in every specification.

E. Denomination-specific regressions

By aggregating all currency denominations along with coins, the different roles of money may not be distinguishable. Consequently, in this subsection we categorize currency into three groups—large, medium, and small. Unlike DGK (2002), the goal of our categorization is to isolate transactional and store of wealth roles of currency. Our priors are that large denominations are primarily used for store of value and affected by short-term interest rates while small denominations and coins are used for transactional purposes and affected by the usage of other payment instruments such as debit cards.

For these regressions, we divide cash outstanding/GDP into three categories— large, medium, and small denominations. The medium note category was chosen by surveying the central banks of the respective countries to determine which denomination was prevalently distributed by ATMs. Denominations above this threshold were categorized as “large,” while those below this threshold (including coins) were categorized as “small.”

In some countries, only a single currency note is commonly distributed by ATMs (e.g., the \$20 note in the United States). In other countries (e.g. Germany), ATMs routinely provide a set of different denominations. In such cases, we categorize all of the ATM-distributed denominations as medium. Table 4 summarizes the data on currency denominations and ATM conventions in each of the countries in our sample. If the main denomination for ATM withdrawals is also the highest denomination (as is the case in Japan with the ¥10,000 note), we categorize it as large.

While the ATM-dispensed banknotes form the bulk of transactional currency demand by volume, they represent a potentially noisy data source for identifying links between the growth of alternative payment instruments and cash demand. We expect smaller denomination notes and coins to be a good gauge of the changing needs of merchants and other receivers of cash to make change for purchases. Since change is given only in the case of cash transactions, changes in the stock of small notes and coins likely provide the most accurate reflection of fluctuations in transactional demand for currency.¹⁴

There are several additional benefits from partitioning the currency by denomination. First, by isolating ATM-distributed notes we attempt to provide a more precise estimate on what we term the ATM demand factor. Given that consumers are primary ATM users and that, in our sample countries, ATMs are the main source of cash for consumers, the primary demand for small denomination notes and coins is by *receivers* of cash to make change. By analyzing non-ATM-distributed notes, we are able to focus on merchant demand for currency. Second, if the share of self-employed affects currency demand by facilitating black market activity, we would expect to identify that relationship in the large denomination category.¹⁵ If, on the contrary, the self-employed stay away from electronic payments for cost reasons, we would expect to find an effect on demand for small denominations. Finally, since the bulk of foreign currency demand is limited to large denominations, we expect the small- and medium-notes demand estimates to be

quite robust to restricting the data sample to countries without substantial foreign demand for their currency.

Table 5 shows the results of fitting a country fixed effects model with cluster-adjusted standard errors to each denomination category. We chose the FE cluster-adjusted specification since its non-parametric formulation gives us a chance to get standard errors right without making strong assumptions. It is also the model in which debit terminals had the weakest statistically identifiable effect on aggregate currency demand (see Table 3). Thus, it sets a somewhat higher hurdle for the denomination-specific exercise.

Panel A of Table 5 contains full sample estimates. As hypothesized, debit card terminals have a very strong negative effect on demand for small denominations, but not for medium or large denominations. This underscores the idea that by eliminating the need to make change, electronic payment instruments have the most measurable effect on the subset of currency used for this purpose. Also, the ATM infrastructure is found to affect only the ATM-dispensed medium category. This effect is fairly precisely identified (p -value of 0.04) and is negative, indicating that, on net, ATM proliferation lowers the stock of medium denomination notes. The bank branch infrastructure has a significant (and positive) effect only on bank-distributed denominations – i.e. those that cannot typically be obtained from ATMs. The ratio of self-employed is influential only for small denomination demand, consistent with the hypothesis of high fixed costs of installing electronic payments terminals for small merchants.¹⁶

Interestingly, we fail to find a statistically measurable effect of short-term interest rates on disaggregated currency demand. Even the large denomination notes, which in their role as store of value should reflect the opportunity costs of currency holdings, have at best a marginally significant effect (p -value of 0.11). However, to the extent that the full sample does not account fully for foreign currency holdings, the estimated response to fluctuations in domestic short-term

rates may be muted. Thus, we repeat the exercise on the truncated sample that excludes Germany, Switzerland, and the United States.

Panel B of Table 5 presents the results for the truncated sample. This time, there is a very strong and precisely identified effect of changes in short-term interest rates on changes in large-denomination currency holdings. Importantly, all other results are very similar to those obtained for the full sample, consistent with the expectation of more stable coefficient estimates across samples. In addition, the full and truncated samples have similar results for small and medium denomination classes, consistent with the assumption that these denominations are less likely to circulate in foreign countries.¹⁷

The specifications in Table 5 do not include time fixed effects in addition to country fixed effects to avoid overfitting a fairly small data set. However, this may raise concerns that the negative relationship between the stock of small denomination currency and the extent of debit card infrastructure is due to secular time trends, which are spuriously reflected in these variables. We believe this concern to be misplaced. Conceptually, the observation that only cash transactions require making change establishes a strong prior of a direct link between the decline in change-making currency and the increase in non-cash payment infrastructure. For this relationship to be due to passage of time (or some other omitted strongly trended variable), one needs to argue that fewer transactions involved small notes and coins, whether for execution or change-making, at the end of our sample than in the beginning. With respect to the former, fairly stable inflation rates over our sample period make it unlikely that the average size of cash transactions changed enough to cross the threshold into the medium-denomination notes. With respect to the latter, price rounding has been rare in countries in our sample. In few places where it occurred, the magnitude of rounding has been far from levels necessary to raise the likelihood of making change for cash transactions in anything other than small denomination currency.¹⁸

5. Conclusion

Despite the strong growth in the adoption of electronic payments throughout the 1990's and the early part of the 21st century, cash usage remains significant in most OECD countries. Although, generally, both consumers and merchants may prefer debit cards to other payment alternatives for certain types of transactions, the resilience of cash demand suggests that electronic alternatives have not succeeded in mimicking all the benefits of cash.

A key feature of our approach is the ability to disentangle cash's dual roles—store of value and payment medium. We are able to isolate the transactional role of cash by focusing on the small denomination class which we define as currency and coin that are lower in value than that commonly dispensed by ATMs. We find that the effects of substitution to electronic payments are largely confined to demand for small-denomination currency, typically used to make change for purchases. Since change is given only in the case of cash transactions, changes in the stock of small notes and coins provide a better gauge of fluctuations in transactional demand for currency. We believe that our paper is the first to attempt identification of cash demand through its “trickling down” to change-making small denomination notes and coins.

We also find that the demand for small denomination currency is not affected by changes in the interest rate, a key feature of the Baumol-Tobin money demand model. Our result is consistent with Alvarez and Lippi (2007) who also find that financial innovations reduce the interest rate elasticity of certain denominations. Their study showcases a stochastic cash inventory model motivated by proliferation of ATMs, and thus the empirical findings focus on ATM-dispensed currency (our medium denomination category). Our finding of substantial interest rate sensitivity of demand for high denomination notes (especially in countries that do not have significant proportions of their currency stock circulate outside of their borders) suggests a persistent role for cash as a store of wealth.

There are several broader long-term implications that follow from our results. First, as ongoing financial innovation lowers the cost of participating in financial markets and raises the returns of doing so, cash holdings may lose some appeal as store of wealth. In this case, currency stocks that are increasingly comprised of large denomination notes, will primarily reflect demand for underground transactions in which anonymity is highly valued. This type of demand for currency may be less sensitive to interest rate movements, potentially resulting in more stable money demand functions. Second, from a public policy perspective, currency may be the preferred medium for the government to collect taxes in the form of seigniorage particularly from otherwise untaxed underground activity. Third, greater conversion to debit cards where change is not required may also decrease the price stickiness of certain types of goods such as vending machine and newspaper purchases that have historically adjusted very infrequently. Indeed, recent research has found evidence of faster price increases for traditionally cash goods (e.g. tollway fees) as payments for them became predominantly electronic (Finkelstein 2007). Moreover, some industry experts argue that consumers are likely to spend more on goods and services when paying electronically because they are not restricted by cash-in-hand and potential psychological constraints.

In sum, our empirical results suggest that electronic alternatives to cash will indeed reduce the demand for cash of certain denominations. However, the general demand for cash will continue to be strong in the future because of cash's anonymity and store of value features. In addition, greater usage of OECD currencies in many emerging economies may result in a shift from domestic money demand in the country of currency issuance to money demand by residents in other countries.

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Data Appendix

We employ three different data sources. For payment data, currency outstanding, population, and banking infrastructure, we use the Bank for International Settlements' Committee of Payment Settlement Systems' *Statistics on Payment and Settlement Systems in Selected Countries* (Red Book) and the European Central Bank's *Payment and Securities Systems in the European Union* (Blue Book).¹⁹ We also contacted several central banks for clarification and to fill in some of the missing data. For short-term interest rates, foreign exchange rates, gross domestic product, and the ratio of self-employed to total employment, we use the International Monetary Fund's *International Financial Statistics*.

The dependent variable in our regressions is the ratio of outstanding currency to GDP. The Red and Blue books provide currency outstanding for each note denominations and coin type. Cash outstanding includes holdings by businesses, individuals and financial institutions but excludes cash held at central banks. For euro countries, we only consider the period from 1988 to 1999, which eliminates the last two pre-Euro years in which currency stocks (particularly those of large-denomination notes) started to decline in anticipation of the regime switch. For the other countries, the sample period is from 1988 to 2003.

In several countries higher denomination coins were introduced during our sample period, replacing, in some cases, paper notes of similar value. In these cases, we kept the coin and note within the same denomination category. In addition, certain currency denominations were replaced by new denominations. In these cases, we kept both new note and the old note that it was replacing in the same category.

As mentioned before, Germany, Switzerland, and the United States have a sizable fraction of their currencies held outside their countries' borders. Since foreign holdings are much less likely to be influenced by domestic cash and debit card infrastructure, we need to

adjust our cash measures. In the case of the United States, we use the Federal Reserve Board's Flow of Funds Accounts series on currency holdings abroad. For Germany, we utilize the time series estimates of Fisher, Kohler, and Seitz (2004).²⁰ Data limitations prevent us from making any adjustments for Swiss currency stocks.

The following variables were taken from the Red and Blue books: number of ATMs, number of POS debit card terminals, number of debit cards, and number of bank branches. Each of these variables was normalized by per capita terms by dividing each variable by the population of each country during that year with the exception of POS debit terminals. POS debit terminals were normalized by 1,000 individuals.

As in any cross-country study, certain variables may not be defined consistently. For example, definitions of debit cards vary somewhat across countries. Although "debit" transactions are usually associated with nearly immediate withdrawal of funds, in some countries (e.g. France) "debit" cards include those in which the funds may be withdrawn up to one month following the transaction. Because in most countries in our sample, PIN-based debit cards are much more widely used than signature-based cards and data for PIN-based transactions are more consistent, we focus on the usage of PIN-based debit cards. In most countries in our sample, all debit cards are PIN-based.

¹ Some recent studies find evidence linking the gradual reduction in check transactions to growing usage of debit cards in the United States (Borzekowski and Kiser 2006; Klee 2006).

² Duca and VanHoose (2004) review this literature.

³ For more recent models using an inventory approach, see Alvarez, Atkeson, and Edmond (2003).

⁴ Lambert and Stanton (2001) and Porter and Judson (1996) discuss foreign demand of U.S. currency.

⁵ For theoretical models that address the link between size of transaction and payment instrument, see Shy and Tarkka (2002) and Whitesell (1992).

⁶ For robustness, we repeated the analysis with currency holdings normalized by total household expenditures. None of the reported results was affected by this modification.

⁷ As a consequence, we have an unbalanced panel in which non-euro countries are over-represented.

⁸ Using transactions data directly to explain fluctuations in cash demand presents an econometric problem. A flow measure of debit card use is an endogenous variable, in the sense that it is influenced by the same factors that affect transactional cash demand. Some of these factors may be unobserved or unavailable, making coefficient estimates on debit card transactions both biased and inconsistent. One example of such an omitted factor is the cost of debit card transactions, which clearly influences both cash and debit use in transacting payments.

⁹ In Amromin and Chakravorti (2007), we regress debit card transactions on the number of debit cards in circulation and debit card terminals. We find that the installation of debit card terminals is able to best explain the increase in debit card transactions.

¹⁰ For more discussion of our data set, see the data appendix.

¹¹ We discuss direct inclusion of tax burden measures into the model in section 4.E.

¹² The results for a full sample of 13 OECD countries are qualitatively similar, although they are somewhat less stable across different econometric models. They are available in the older

version of the paper (Amromin and Chakravorti 2007). In the subsequent analysis of denomination-specific demand, we report the results for both sets of countries, as foreign demand is limited to large-denomination currency.

¹³ We also estimated the model under the assumption of first-order autocorrelated error terms, as well as the random-effects model with clustered standard errors. Both of those methods of accounting for within-country serial correlation resulted in somewhat smaller changes to the pooled OLS estimates.

¹⁴ In the United States, some merchants, such as grocery stores, are willing to give cash back to their debit card customers. This service is analogous to cash back received for checks, a common means to acquire cash in the 1980s. Some analysts have suggested that these merchants provide cash back services to reduce their cash handling costs. However, this practice is not widespread for most countries in our sample.

¹⁵ Arguably, even the lemonade stand operator wishing to avoid tax payments would at some point have to convert coins and small denomination notes it collects for larger notes suitable for storing wealth or transacting.

¹⁶ We experimented with adding various measures of the tax burden to the regression. Among the variables we evaluated were: the statutory point-of-sale tax rates (VAT or the weighted sales tax rate), average marginal tax on earned income, and both the contemporaneous and the lagged ratio of tax revenues to GDP. In each case, we failed to detect a significant direct effect of tax burden measure on demand for any denomination class. This is consistent with at least some studies of cash demand in OECD countries (Boeschoten 1992; Doyle 1999). More importantly, none of the results reported in Table 5, was materially affected by any of the tax variables.

¹⁷ In Amromin and Chakravorti (2007), we also report regressions using DGK breakdown.

While we find similar qualitative results, the precision of the results improves by considering three categories instead of two.

¹⁸ For instance, Finland and the Netherlands do not issue eurocent coins and encourage merchants to use 5-cent increments in setting prices. Although this development took place outside our sample window, it is indicative of the type of denomination-specific change associated with rounding.

¹⁹ We used the Blue Book for Austrian and Finnish data.

²⁰ Since holdings of domestic currency abroad are heavily concentrated in large denomination notes (Porter and Judson 1996), we subtract the estimated foreign holdings from large denomination notes series for both Germany and the United States.

Figure 1: Per Capita Debit Card Volume

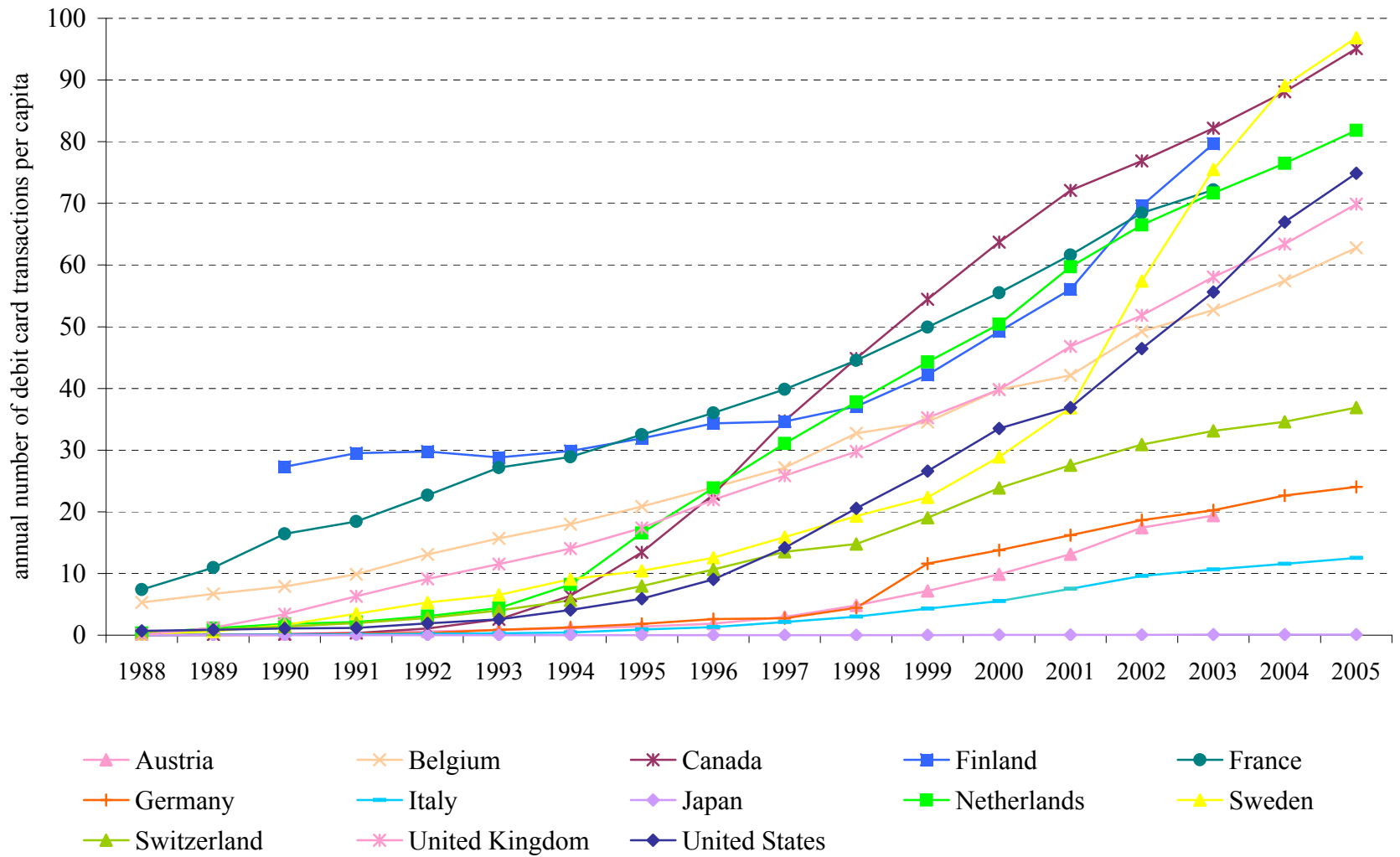
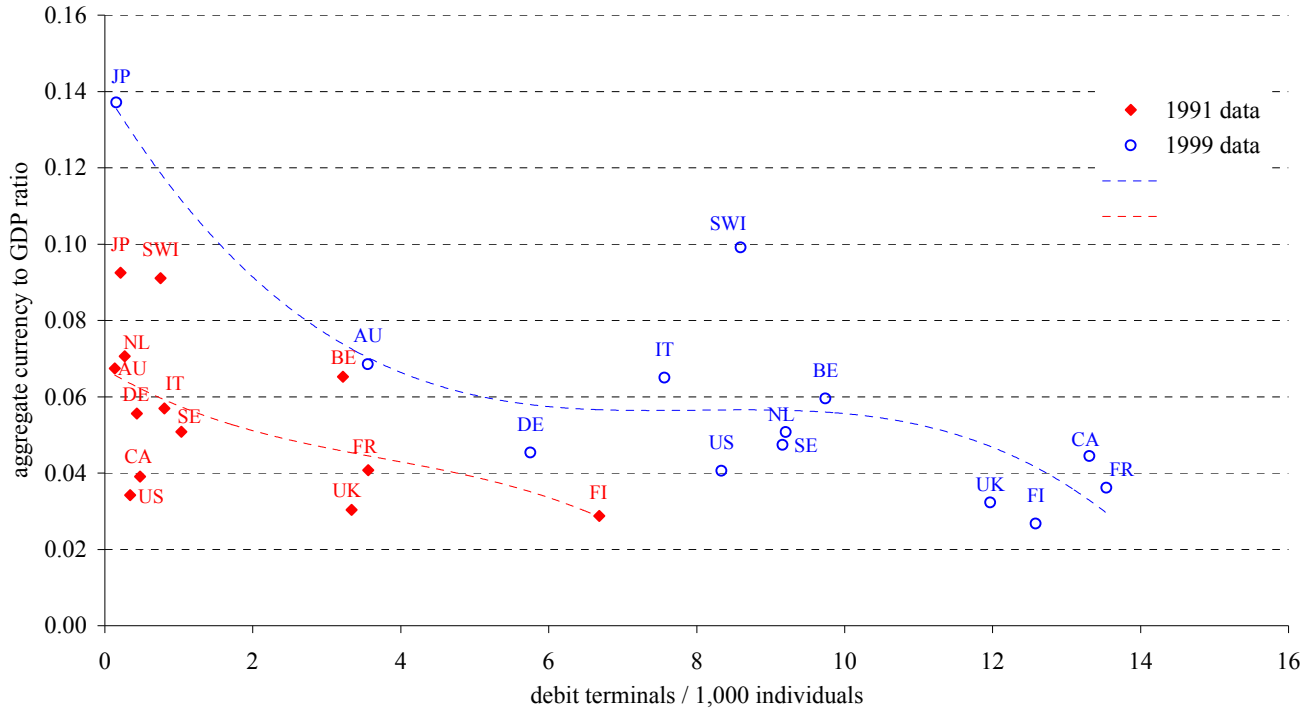


Figure 2. Aggregate Currency Stock and Debit Terminal Infrastructure
(13 OECD countries in 1991 and 1999)



Sources: Bank for International Settlements' Committee of Payment Settlement Systems' Statistics on Payment and Settlement Systems in Selected Countries (Red Book) and the European Central Bank's Payment and Securities Systems in the European Union (Blue Book)

Note: Data on currency/GDP ratio are adjusted for currency circulating abroad (see Appendix for details). The diamonds depict the relationship between the aggregate currency/GDP ratio and the debit card infrastructure in 1991, while the hollow dots depict the same relationship at the end of the decade. The corresponding dashed lines represent cubic splines fitted to the data points in a given year.

Table 1. Number of Per Capita Non-Cash Payments by Type of Instrument, 2005

	Checks	Electronic Payments			Total Non-Cash Payments	<i>Reference:</i>
		Debit and Credit Cards	Direct Credits	Direct Debits		Total Non-Cash Pmts. In 2001
Austria	1	32	113	81	227	213
Belgium	2	71	78	21	171	151
Canada	42	156	27	19	243	220
Finland	0	129	119	14	261	221
France	63	84	45	63	254	219
Germany	1	29	81	81	192	163
Italy	8	20	18	8	54	50
Japan	1	39	11	NAV	51	31
Netherlands	0	86	75	63	224	214
Sweden	0	118	57	18	192	146
Switzerland	0	51	82	7	140	130
United Kingdom	32	104	50	45	231	203
United States	112	145	19	25	300	275

Source: BIS CPSS Red Books and ECB Blue Books various years.

Table 2. Self-Employed Ratio and Shadow Economy

Country	Self-employed ratio (1999)	Shadow Economy as % of official GDP (1999)
France	7.65	15.20
United States	7.65	8.70
Sweden	8.17	19.20
Germany	10.04	16.00
Finland	12.09	18.10
United Kingdom	12.56	12.70
Switzerland	13.80	8.60
Netherlands	14.00	13.10
Canada	17.04	16.00
Belgium	17.06	22.20
Japan	17.51	11.20
Austria	20.73	9.80
Italy	33.88	27.10

Source: IMF; shadow economy estimates are from Schneider (2006).

Table 3. Various Econometric Models of Aggregate Currency Demand

	(1)	(2)	(3)
Dependent variable: currency stock / GDP ratio	Pooled OLS	Fixed Effects (FE)	FE with cluster-adjusted SE
log(Debit terminals/pop)	-0.116** (0.014)	-0.024** (0.009)	-0.024 (0.012)
log(ATMs/pop)	-0.128** (0.041)	-0.034 (0.019)	-0.034 (0.031)
log(Bank branches/pop)	0.261** (0.073)	0.352** (0.048)	0.352** (0.078)
log(Ratio of self-employed)	0.229** (0.047)	0.221* (0.104)	0.221 (0.220)
log(Short-term interest rate)	-0.307** (0.032)	-0.092** (0.019)	-0.092** (0.021)
Y2K dummy	-0.001 (0.067)	0.038 (0.031)	0.038 (0.022)
constant	-2.991	-3.278	-3.278
N	128	128	128
Goodness-of-fit measure	adj. R ² 0.71	within R ² 0.43	within R ² 0.43

Note: All specifications are estimated on a subsample of 10 OECD countries. This subsample excludes countries with a large share of currency circulating outside national borders -- Germany, Switzerland, and the United States.

Specification (2) allows country fixed effects, while specification (3) corrects the standard errors for within-country serial correlation by using cluster adjustments. ** and * denote statistical significance at the 1 and 5 percent levels, respectively. Standard errors are in parentheses.

Table 4. Highest Denomination and ATM notes in 13 OECD countries

National Currency	<u>Highest Denomination</u>		<u>Most common ATM note</u>		<i>December 31, 2000</i>
	NCU	US \$	NCU	US \$	Exchange rate (NCU/\$)
Austria Schillings	5,000	\$342	100 - 1,000	\$7 - \$68	14.61
Belgium Francs	10,000	\$234	1000	\$23	42.82
Canada Dollars	1,000	\$667	20	\$13	1.50
Finland Markka	1,000	\$158	100	\$16	6.31
France Francs	500	\$72	100	\$14	6.96
Germany Deutsche Marks	1,000	\$482	10 - 100	\$5 - \$48	2.08
Italy Lire	500,000	\$243	10K - 50K	\$5 - \$24	2055.49
Japan Yen	10,000	\$87	10000	\$87	114.35
Netherlands Guilders	1,000	\$427	100	\$43	2.34
Sweden Kronor	1,000	\$106	100 - 500	\$11 - \$53	9.40
Switzerland Francs	1,000	\$621	20 - 200	\$12 - \$124	1.61
United Kingdom Pounds	50	\$75	10 - 20	\$15 - \$30	0.67
United States Dollars	100	\$100	20	\$20	1.00

Source: CPSS Red and ECB Blue Books and correspondence with central banks.

Table 5. Denomination-specific currency demand: FE model with cluster-adjusted SEs

Currency classification
Large: greater than ATM-dispensed
Medium: ATM-dispensed notes
Low: less than ATM-dispensed notes + coin

Panel A: 13 OECD countries, pre-Euro if applicable

Dependent variable:	<i>logarithm of</i>		
	Large/GDP	Medium/GDP	Small/GDP
log(Debit terminals/pop)	-0.005 (0.030)	0.025 (0.029)	-0.043** (0.012)
log(ATMs/pop)	-0.030 (0.103)	-0.242* (0.108)	0.000 (0.036)
log(Bank branches/pop)	0.424* (0.168)	0.212 (0.204)	0.275* (0.094)
log(Ratio of self-employed)	-0.344 (0.308)	0.286 (0.221)	0.318** (0.101)
log(Short-term interest rate)	-0.061 (0.037)	-0.044 (0.028)	-0.022 (0.015)
Y2K dummy	0.018 (0.053)	0.022 (0.029)	-0.002 (-0.015)
constant	-2.566	-4.950	-5.812
N	169	169	169
Goodness-of-fit measure	within R ² 0.07	within R ² 0.21	within R ² 0.66

Panel B: 10 OECD countries, pre-Euro if applicable; exclude Germany, Switzerland, and US as countries with a large share of currency abroad or out of circulation.

Dependent variable:	<i>logarithm of</i>		
	Large/GDP	Medium/GDP	Small/GDP
log(Debit terminals/pop)	-0.028 (0.025)	0.029 (0.026)	-0.044** (0.014)
log(ATMs/pop)	0.052 (0.066)	-0.267* (0.097)	0.004 (0.039)
log(Bank branches/pop)	0.475* (0.186)	0.260 (0.201)	0.301* (0.101)
log(Ratio of self-employed)	0.218 (0.249)	0.239 (0.440)	0.396* (0.147)
log(Short-term interest rate)	-0.131** (0.025)	-0.035 (0.046)	-0.030 (0.019)
Y2K dummy	0.054 (0.033)	0.000 (0.031)	-0.009 (-0.018)
constant	-3.806	-4.999	-6.068
N	128	128	128
Goodness-of-fit measure	within R ² 0.26	within R ² 0.46	within R ² 0.64

Note: All specifications are estimated with country fixed effects, with standard errors adjusted for within-country serial correlation by using cluster adjustments. ** and * denote statistical significance at the 1 and 5 percent levels.