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**Debit Card and Cash Usage:
A Cross-Country Analysis**

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Abstract

During the last decade, debit card transactions grew rapidly in most advanced countries. While check usage declined and has almost disappeared in some countries, the stock of currency in circulation has not declined as fast. We use panel estimation techniques to analyze the change in transactional demand for cash resulting from greater usage of debit cards in 13 countries from 1988 to 2003. We are able to disentangle cash's store of value function from its payment function by separating cash into three denomination categories. We find that the demand for low denomination notes and coins decreases as debit card usage increases because merchants need to make less change for customer purchases. On the other hand, the demand for high denomination notes is generally less affected suggesting that these denomination notes are also used for non-transactional purposes.

Key words: payment networks, money demand, consumer choice, technological infrastructure
JEL Classifications: D23, E41, G21

In this article, we study the factors influencing the adoption of electronic payment alternatives such as debit cards and their impact on cash usage. This area of research is relevant for several reasons. First, greater usage of cash substitutes affects how much cash the central bank should supply. Economists continue to debate the implications of a possible reduction in currency demand for monetary policy (Buiter, 2005; Chakravorti, 2006; Freedman, 2000, Friedman, 1999; Goodhart, 2000; Kroszner, 2003; Woodford, 2000). One consequence of lower demand for cash is a decrease in seigniorage revenue. Humphrey, Kaloudis, and Øwre (2004) view outstanding currency as interest-free loans and if there is a significant reduction in the quantity of cash in circulation resulting from the use of alternative payment instruments, the potential loan repayment would be very large. Second, some economists have suggested social welfare would improve if fewer cash transactions occurred (De Grauwe, Buyst, and Rinaldi 2000; Van Hove, 2004a). However, whether the number of cash transaction has indeed declined in recent years proved to be a tricky empirical question, owing to difficulties in separating cash's payment function from its store of value function. Third, the relationship between the willingness of consumers and merchants to adopt non-cash payment alternatives and the pricing of those payment instruments has attracted considerable research attention (Chakravorti and McHugh, 2002; Humphrey, Pulley, and Vesala, 1996; Markose and Loke, 2002; Rochet and Tirole, 2003). Any debate on the pricing of payment instruments should start with studying the factors influencing the migration from cash to other payment media. Our analysis provides a necessary first step to address these issues.

We discuss payment trends in thirteen 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 and check usage continues to decrease or has almost disappeared.

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 value 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. This task is complicated further by the unique anonymity feature of cash, which is valued highly by those trying to avoid detection by the public authorities. Cash transactions are more difficult to trace to the transactors because it can be used multiple times without third-party intervention unlike payment cards where each transaction is converted to good funds. Consequently, cash has an enduring appeal for facilitating illicit transactions, as well as for storing ill-gotten (or, at least, untaxed) wealth (Drehmann, Goodhart, and Krueger, 2002).

Our analysis differs from the existing literature in the following ways. First, we decompose cash demand by currency denomination type 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. Although ATM-dispensed banknotes form the bulk of transactional currency demand by volume, analysis of fluctuations in such "medium-value" denominations presents a number of empirical challenges. In particular, the rapid growth of ATM networks over the past two decades had a theoretically ambiguous effect on observed quantities of medium-value notes in circulation. On the one hand, more ATMs may have reduced the stock of such notes by lowering transaction costs of obtaining them. On the other hand, the need to stock a larger number of ATMs with currency to be dispensed may have generated the opposite effect. Consequently, medium-value banknotes represent a noisy data source for establishing a relationship between the growth of alternative payment instruments and cash demand. In contrast, the demand for smaller denomination notes and coins is unaffected by secular changes in ATM networks. Rather, we argue that these forms

of cash capture the demand by 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 provide a better gauge of fluctuations in transactional demand for currency. Although other papers employed currency decomposition by denomination (see e.g. Drehmann, Goodhart, and Krueger, 2002; Fischer, Köhler, and Seitz, 2004; and Porter and Judson, 1996), we believe that ours is the first paper to attempt identification of cash demand through its "trickling down" to change-making small denomination notes and coins.

Second, we employ different econometric techniques than those commonly used in this literature to address strong serial correlation that is present when analyzing annual cross-country payments data. We show that results depend importantly on the choice of the econometric model. Finally, our data covers the time period of rapid growth 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.

Providers of debit card services must convince both consumers and merchants to use them over existing and emerging payment alternatives. We find that enabling consumers to use debit cards is not sufficient to increase their usage. The recent payments literature using a two-sided market framework highlights the importance of having both sides—payors and payees—on board (Armstrong, 2004; Rochet and Tirole, 2003). Consumers, for the most part unknowingly, added debit cards to their wallets because they were mainly seen as devices to access cash and make deposits at automated teller machines (ATMs) that became popular almost a decade before widespread debit card usage. They were unable to use their cards to make purchases until merchants adopted POS debit terminals. While adoption of payments technology by end-users does not guarantee widespread usage, in the case of debit cards, we show that adoption of debit

card terminals by merchants was the critical step that led to the explosive growth in debit card transactions.

Finally, we study the impact of debit card usage on the stock of currency and coin outstanding. The impact of debit cards varies by currency denomination category. We find that larger denomination notes are affected by the short-term interest rate but not by the adoption of POS debit card terminals. However, both debit card infrastructure and financial institution branch infrastructure significantly affects the demand for small denomination notes and coins whereas the short-term interest rate has little effect. This result supports the hypothesis that small denomination notes and coins are required to make change for purchases when cash is used. If cash is not used, the demand for change and consequently the demand for small denomination notes and coins both decrease. Because financial institutions are the main distributors of small denomination notes and coins, less debit card usage requires a more extensive branch network to distribute and collect small denomination notes and coins.

This article is organized as follows. In section 1, we discuss payment trends across the countries in our sample. In section 2, we review the literature that analyzes the impact of electronic payment alternatives on cash. We discuss the data in section 3 and analyze the key factors driving the adoption of debit cards in section 4. In section 5, we focus on the relationship between the adoption of debit cards and changes in the stock of cash, broken by denomination categories. We offer some concluding remarks in section 6.

I. Cross-Country Payment Trend Comparisons

While there are major differences in banking and regulatory structures along with differences in cultural attitudes toward payments between countries in our sample, certain common payment trends exist. First, debit card usage grew rapidly during the 1990s in most

countries in our sample. In Figure 1, we plot debit card transactions over time by country. In

1988, all countries except for Finland had less than 10 debit card transactions per person per

year. By 2004, all countries except Japan had more than 10 transactions per person per year and

several had more than 60. The increase in debit card transactions suggests that the net benefits of

using debit cards have increased vis-à-vis other payment instruments for consumers and

merchants (assuming that the total number of transactions is growing at a slower rate than debit

card transactions.)

The second common trend is that check usage continues to decrease in most countries

and has disappeared in many countries. There are eight countries where on average less than two

checks per person were written in 2004 (see Table 1). Even in countries with a relatively high

number of check transactions such as Canada (43 checks/person), France (66 checks/person), the

United Kingdom (35 checks/person), and the United States (119 checks/person), check usage

continues to decline. Some studies find that debit cards have substituted for check transactions

(Borzekowski and Kiser, 2006 and Klee, 2006).

Third, cash has not disappeared from these countries although several cash substitutes

exist.[1] While general-purpose stored-value cards have not been widely adopted, other general-

purpose payment instruments, e.g. credit and debit cards, can now be used for transactions in

environments that were until recently "cash only."[2] Mass transit and fast food restaurants

represent just two of the more ubiquitous industries where such switch took place. Some surveys

of merchants and consumers suggest that cash demand for transactions is decreasing in many

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[1] Originally, checks were a cash substitute. Humphrey (2004) reports that in addition to replacing cash transactions for consumer payments, employee disbursements, and smaller-value business purchases shortly after the Civil War, checks were used until 1915 for large-value business transactions and interbank transfers in the United States.

[2] For more on the lack of widespread acceptance of general-purpose stored value, see Chakravorti (2004) and Van Hove (2004b). More recently, prepaid cards have become popular for certain applications such as gift giving and disbursement of payroll and government benefits in the United States. For more details, see Chakravorti and Lubasi (2006).

countries (American Bankers Association and Dove Consulting, 2005; Jyrkönen, 2004; Stix, 2003).

One metric to compare cash transactions across countries is the total per capita annual *non-cash* transactions. Generally, greater use of non-cash payment instruments indicates a lesser reliance on cash as a payment medium.[3] The number of non-cash transactions per capita in 2004 (Table 1) ranges from 36 for Japan to 288 for the United States. Furthermore, non-cash transactions have increased between 2001 and 2004 for all countries in our sample, suggesting a reduction in cash transactions over time within a country.

Two measures of overall cash demand are cash holdings per capita and cash outstanding to GDP ratio. However, these two measures are unable to distinguish between cash's store of value and payment functions. In Table 2, we compare countries by their per capita currency holdings (in US dollars) and their ratio of the stock of currency to GDP in 1998.[4] Currency per capita ranges from $613 for Finland to $3,620 for Japan. Similarly, the currency to GDP ratio ranges from .024 for Finland to .116 for Japan. For the most part, the ordering of countries is similar for both "stock" measures of currency demand. The ordering is also consistent with the "flow" measure of currency demand summarized in Table 1.[5]

Several researchers have noted that it is unlikely that the average individual in these countries hold this much cash. Rogoff (1998) states that between 70 percent to 80 percent of OECD currency stock is either held by the domestic underground economy or in developing countries. In addition to household cash holdings, Rogoff argues that businesses (presumably legal ones) are very efficient in cash management and are not likely to hold much cash in OECD

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[3] Humphrey, Pulley, and Vesala (1996) were the first, to our knowledge, to use this metric to compare cash usage across countries.

[4] We chose 1998 to stay sufficiently far from the introduction of the euro in 2002 and the increase in Y2K precautionary supply in 1999 for some countries.

[5] Germany, Switzerland, and the United States represent important exceptions, since a substantial share of the currency stock of these countries is estimated to be held abroad. We address this issue below.

countries. While it is difficult to measure underground activity, some estimates suggest that it is sizable. Schneider (2006) estimates that the shadow economy in 21 OECD countries averaged 16.3 percent of GDP during the period 2002-2003. He states that the primary justification for why transactions take place in the shadow economy is tax avoidance.

For certain countries, these measures overstate domestic cash usage because significant holdings of their currencies are held outside their countries' borders. U.S. dollars being held outside of the United States have been estimated to be around 60 percent of total currency in circulation (U.S. Department of Treasury, 2003).[6] Prior to the introduction of the Euro in 2002, up to forty percent of deutsche marks circulated outside of Germany (Seitz, 1995). Large portions of Swiss francs are believed to be either held outside of Switzerland or held in safe deposit banks inside the country (Boeschoten, 1992; Fischer, Köhler, and Seitz, 2004; and Rogoff, 1998). Rogoff (1998) also suggests that a non-trivial amount of Japanese currency is probably held outside of Japan but there is little hard evidence.

Several economists have attempted to quantify legal currency usage by studying consumption patterns.[7] For instance, Humphrey (2004) calculates total cash purchases as the residual of personal consumption that is not captured by check, debit card, or credit card registered transactions. Humphrey eliminates $50 and $100 notes from his estimation to better gauge legal uses of currency. Humphrey estimates that cash share of legal consumer payments fell from .31 in 1974 to .20 in 2000 in the United States.

For Sweden, Andersson and Guibourg (2001) estimated that cash payments in registered sales (those for which value-added tax are collected) declined by 18 percent between 1991 and 1999. They suggest that almost all of the decline has been due to greater usage of payment

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

[7] See Carbo Valverde, Humphrey, and Lopez del Paso (2003), Humphrey, Kaloudis, and Øwre (2004), and Snellman, Vesala, and Humprey (2001).

cards. However, they are unable to explain 45 percent to 65 percent of cash holdings. They

suggest that anonymity may be a critical factor in continued cash usage especially for

transactions that use the 1,000 Swedish krona note.[8]

II. Literature Review

The theoretical literature on money demand is quite large.[9] Many models extend the

Baumol (1952)-Tobin (1956) model where interest rates, income, and the acquisition costs of

cash including shoe leather costs, determine the supply of money. Payment practices and

transactions costs are fundamental features of these models.[10]

This article best fits in the empirical literature that investigates changes in cash demand

resulting from the adoption of new payment infrastructure for cash or non-cash payment

alternatives. The empirical literature on cross-country payment usage continues to grow.

Extensive research in the area of Dutch currency usage and the adoption of alternative payment

media was done by Boeschoten (1992). He noted the difficulty in disentangling the transactional

use from other uses of currency, most notably hoarding. He found that adoption of credit cards

and "point-of-sale transactions" were responsible for 40 percent of the fall in currency ratio

between 1965 and 1975. However, this trend reversed from 1975 to 1990 indicating an increased

role for banknotes as a store of value. He estimates that 50 percent to 60 percent of the Dutch

currency was hoarded in 1990.

In addition to his study of Dutch money demand, Boeschoten estimated money demand

using a 15-country panel. He found significant hoarding in these countries as well. He was able

to predict future currency holdings based on the adoption of payment cards but not for all the

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[8] As of December 31, 2006, the Swedish krona/U.S. dollar rate was 6.85.

[9] Duca and VanHoose (2004) reviews this literature.

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

countries in his sample. He also analyzed percentage of currency held by financial institutions and found that on average 13 percent of currency outstanding is held by financial institutions for the countries in his sample.

Humphrey, Pulley, and Vesala (1996) (henceforth HPV) studied the factors influencing the migration to less costly payment alternatives such as debit cards and electronic and paper giros. They looked at 14 countries for the time period from 1987 to 1993. They used five regressions where the dependent variable was the annual transactions volume of one of the five payment instruments (check, electronic or paper giro, credit card, and debit card). Their independent variables included the prices of each payment instrument (only available for 10 of the countries), real GDP, number of POS and ATM terminals, lagged volumes of the other payment instruments, cash holdings per person, violent crime, and concentration ratio of the largest five banks.

They found the following. The influence of prices was modest because often prices for payment instruments did not vary much during their sample period and bundled across all account services. POS and ATM terminals are strongly positively related to debit card usage suggesting that similar infrastructure is used. They found that all payment instruments except for debit cards substitute for cash. The institutional variables measuring crime and banking concentration were not stable across different econometric models.

Unlike HPV, Drehmann, Goodhart, and Krueger (2002) (henceforth DGK) regress aggregate cash holdings per capita on several macro variables (real GDP per capita, nominal interest rates, and tax GDP ratio), two payment infrastructure variables (ATMs and POS terminals), and crime. They divide currency into large bills (greater than 50 British pounds) and small bills (less than 50 British pounds). Their rationale for this division is to separate illegal use of cash from transactional use. While they get significant estimates for the coefficients for the

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macro variables, they do not get significant results for the payment infrastructure variables or crime.

Another approach to isolate the impact of debit cards on cash usage is to survey individuals and their payment habits. While surveys of relatively small sample of individuals over a small period of time has its limitations, these studies may help to explain the demand for cash given payment alternatives from a microeconomic aspect that is not present in aggregate studies of money demand. For Austria, Stix (2003) finds that those individuals that make purchases frequently with debit cards on average hold 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 and where the purchase is made are key factors for the consumer choice of a payment instrument.[11] They also find that cash and checks, not surprisingly, are common when merchants do not accept payment cards. In addition, they are able to confirm well-established demographic factors that determine payment usage such as age, education, and gender.

III. Data

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).[12] We also contacted several central banks for clarification and to fill in some of the missing data. For short-term interest rates, foreign

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

[12] We used the Blue Book for Austrian and Finnish data.

exchange rates, gross domestic product, and the ratio of self-employed to total employment, we use the International Monetary Fund's *International Financial Statistics*.

A key dependent variable in our regressions is the ratio of outstanding currency to GDP. 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.

For certain regressions, we divide cash outstanding/GDP into three categories— large, medium, and small denominations. The Red and Blue books provide currency outstanding for each note denominations and coin type. The medium denomination 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 denominations, while those below this threshold (including coins) were categorized as small denominations.

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 3 summarizes the data on currency denominations and ATM conventions in each of the countries in our sample. The large category includes denominations above "medium" and small includes denominations below "medium" along with coins. If the highest denomination is also the main denomination for ATM withdrawals (as is the case in Japan with the ¥10,000 note), we categorize it as large. Other currency such as a US $2

banknote, commemorative or limited edition coins or banknotes were excluded from the denomination data.

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 in the introduction, 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 Flow of Funds Accounts series on currency holdings abroad. For Germany, we utilize the time series estimates of Fisher, Kohler, and Seitz (2004).[13] 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, number of checks, and number of bank branches. Each of these variables was normalized to 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 10,000 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

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

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.

IV.   Adoption of Debit Cards

The ultimate goal of this paper is to understand the relationship between electronic cash substitutes like debit cards and demand for currency. Observed debit card transactions appear to be a good gauge of the extent to which such cards represent a viable alternative to cash. However, using transactions data directly to explain fluctuations in cash demand presents two empirical problems. The first problem is one of measurement. In several countries, reported debit card transaction data are incomplete, in the sense that they only capture a part of debit card payments. For instance, in the United States, signature debit card payments are executed over credit card networks and do not consistently appear as a part of "debit" transactions. In some cases, credit and debit card transactions are not separated, e.g. France. The second problem is econometric. 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 use, which clearly influences both cash and debit use in transacting payments.

To circumvent these problems to some extent, we rely on measures of debit card infrastructure rather than usage, namely, the number of debit cards in circulation and the number of debit card terminals. Both of these variables are measured more precisely, and are less likely to be directly affected by omitted factors influencing cash usage. For example, the consumer

cost of a debit card transaction is less likely to be reflected in the number of debit card terminals installed by merchants. Yet, it may offer a reasonable proxy of merchant expectations on debit card use at the point of sale.

Instrumenting debit card usage by these infrastructure variables has an additional benefit in that it allows us to study the factors influencing debit card adoption. In particular, we are interested in whether consumer or merchant acceptance contributed to the takeoff of debit cards and an alternative payment instrument. As mentioned before, debit and ATM functionality usually reside on the same card. Therefore, many debit cards were held by consumers before they were able to use them to make purchases. On the other hand, merchant acceptance was contingent on the expectation that debit cards would be used if terminals were installed and the net benefits of accepting debit cards were greater than accepting alternative payment media.

Clearly, a key factor in deciding to accept debit cards is the cost of doing so. Recently, economists have applied two-sided market analysis to payment cards to study pricing of payment services.[14] The literature on two-sided markets stresses that the proportion of the total price paid by each end-user group need not be symmetric to achieve optimal usage levels. In fact, many two-sided markets have asymmetric pricing between end-users such as newspapers (readers and advertisers), Adobe Acrobat (creators and readers of PDF files), and dating clubs (women may be let in at a reduced price and men pay a higher fee).

For the most part, consumers do not pay per-transaction debit card fees.[15] Although there may be a bundled fee for a transaction account, once that is paid the marginal cost to use a debit card is close to zero. In most instances, merchants that accept debit cards face fixed and per-

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[14] For more on two-sided markets, see Armstrong (2004) and Rochet and Tirole (2003).

[15] There are some exceptions. While not common, a few U.S. merchants impose surcharges on PIN-based debit transactions (Chakravorti and Shah, 2003). In addition, some U.S. financial institutions impose per-transaction fees for PIN-based debit card transactions.

transaction fees.[16] While we do not have pricing data, we can compare adoption of debit cards

by consumers and merchants by looking at the number of debit cards and debit terminals,

respectively.

Table 4 presents data on the number of debit terminals per 10,000 individuals along with

debit cards/person in 2003.[17] Countries in our sample that have high debit card usage also

generally have high card adoption by consumers and high adoption of terminals by merchants.

However, this relationship is far from uniform. For instance, Italy has relatively few debit cards

per capita despite having a high number of debit terminals. Also noteworthy is that while Japan

has three times as many debit cards in circulation as residents, the adoption of debit terminals is

the lowest in our sample. Thus, both debit terminals and debit cards are required for a high

number of debit card transactions.

To study the evolution of debit card usage within a country, we use a fixed effects

econometric model with clustered standard errors. Specifically, our regression is:

$$Debit\ Transactions_{it} = \alpha + \beta_1\ Debit\ Cards_{it} + \beta_2\ Debit\ Terminals_{it} + \beta_3\ ATMs_{it} + \beta_4\ Checks_{it} \quad (1)$$

$$+\ \beta_5\ Bank\ Branches_{it} + \beta_6\ Share\ of\ Self\text{-}Employed_{it} + \beta_7\ STIR_{it} + \varepsilon_{it}$$

Using the country fixed effects specification means that we are effectively trying to

explain changes in debit card acceptance in a given country by changes in debit card

infrastructure and in control variables. These control variables are intended to capture

competitive pressures from other payment instruments (cash and checks), as well as the costs of

facilitating debit card transactions.

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[16] Van Hove (2004b) reports that merchants in Denmark do not pay any per-transaction fees when accepting debit cards.

[17] Canada is an exception, as the number of debit cards there was last reported in 2000.

To lessen endogeneity concerns mentioned above, we use measures of the extent of cash infrastructure to proxy for cash "competitiveness." These measures are the number of ATMs and bank branches. The relationship between debit card usage and ATM is ambiguous because greater usage of ATMs may encourage greater comfort with card payments. On the other hand, a greater number of ATMs allows easier access to cash and may lead to greater dependence on cash for payments. Similarly, more bank branches suggest lower acquisition costs of cash, thereby encouraging greater reliance on cash. For alternative paper-based payment infrastructure, we include check volumes. Many U.S. studies have suggested that debit cards substitute for checks. In countries that use checks, we would expect a negative relationship between debit card and check transactions.

The cost of facilitating debit card transactions depends, in part, on merchant size distribution. 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 still have to accept cash and still 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. One proxy for such measure is provided by the ratio of the self-employed to total employment. In Table 5, we report these ratios for 1998. Note that Italy, Austria, and Japan are near the bottom in debit card transactions and are the top three in terms of proportion of self-employed to total employment. While fixed effect panel estimation does not allow analysis of the cross-sectional relationships, we use this variable to control for consolidation in the retail industry. A more traditional measure of cost of debit card use is their opportunity cost relative to non-interest-bearing payment instruments such as cash. To the extent that demand deposit accounts linked to debit

cards generate a positive (albeit low) nominal rate of return, we would expect the number of debit card transactions to rise with short-term interest rates.

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 debit card transactions, debit cards in circulation, ATMs, checks written, and bank branches is expressed in per capita terms, while the number of point-of-sale debit card terminals is defined in units per 10,000 residents.[18] The Share of Self-Employed is based on the IMF annual employment composition data for each country, and $STIR_{it}$ is defined as the short-term interest rate in country i in year t.

In Table 6, we report our regression results. Shading indicates coefficient estimates that are statistically significant at least at the 5 % level. In regression (1) (column 1 in Table 6), the only variable proxying for debit card infrastructure is the number of debit cards, which is found to be a strong indicator of greater debit card use. In this specification, the number of ATMs also has a significant positive effect on debit card transactions, while checks detract from debit card usage. The sign on self-employed is opposite from what we expected, as is that on the short-term interest rate.

However, these results are sensitive to a specific measure of debit card infrastructure. In regression (2) that uses the number of debit card terminals, none of the control variables (with the exception of the short-term interest rate) retains statistical significance. This result persists when both debit card terminals and cards are used in the regressions (column 3 in Table 6). Moreover, in that specification only the number of debit card terminals remains a strong predictor of debit card usage. Taken together, these results suggest that merchant adoption is driving debit card usage, and that the number of debit card terminals is indeed a strong instrument for transactional demand for debit cards.

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[18] Check data prior to 2001 does not exist for the United States.

V. Debit Cards and Cash Substitution

In this section, we study the impact on the cash/GDP ratio resulting from changes in payment infrastructure, merchant size distribution and the opportunity cost of holding cash. We assume that central banks provide an elastic supply of currency. Therefore, supply of cash equals demand for cash. All countries in our sample had their own currencies until 2002 when the Euro was introduced. Austria, Belgium, Finland, France, Germany, Italy, and the Netherlands are part of the euro area and have not issued their own currencies since 2002. 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 plot a time series of currency to GDP ratios in figure 2. The ratio was decreasing for most countries throughout the 1970's and much of the 1980's, but flattened out for most countries since then reflecting, in part, successful stabilization of inflation. A number of geopolitical shocks that occurred since 1988 had a measurable effect on demand of certain currencies. In particular, the unification of Germany and disintegration of Yugoslavia resulted in increased 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). The increased demand for Japanese yen is partly attributable to an extremely low or negative inflation environment over the past 15 years.

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:

$$(Currency/GDP)_{it} = \alpha + \beta_1\, Debit\ Card\ Terminals_{it} + \beta_2\, ATMs_{it} + \beta_3\, Bank\ Branches_{it} \quad (2)$$

$$+ \beta_4\, Share\ of\ Self\text{-}Employed_{it} + \beta_5\, STIR_{it} + \varepsilon_{it}$$

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. 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.[19]

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 a measure of competing payment instruments.

As argued in the previous section, the number of debit card terminals at the point of sale is a strong instrument for the demand for debit card transactions that likely substitute for some cash transactions.[20] In Figure 3, we provide a cross-country snapshot in 1998 of the relationship between currency/GDP ratio and the number of debit terminals. In general, countries with a high number of debit card terminals tend to have lower currency/GDP ratios suggesting broadly that debit cards may be substituting for cash transactions.

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

[20] Debit cards could substitute for other non-cash transactions as well. If debit cards substituted for only non-cash transactions, the demand for cash would not be affected by debit card transactions.

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 ambiguous. On the one hand, greater number of ATMs potentially increase the velocity of cash as consumers can access cash more easily. Hence, more ATMs would imply lower currency stocks.

However, the relationship between ATMs and cash may be changing over time depending on debit card usage at the point of sale. Initially, the introduction of ATMs increases the demand of cash of which a part is in response to filling ATMs with cash by ATM operators. In other words, a decrease in demand for cash by individuals is offset by increased demand to fill ATMs which may require idle cash especially if they are not serviced daily. The demand by ATM operators for cash may be greater than the reduction of cash holdings by consumers especially when the number of ATMs and transactions are increasing.[21] Once the number of ATMs has stabilized and/or the amount of withdrawals per machine decreases resulting from greater usage of debit cards, the demand for cash by ATM operators would fall.[22]

We use the number of branches of financial institutions as a measure for cash access especially for non-ATM dispensed notes and coin. 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

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[21] ATM owners may overstock their machines since they face reputational harm if their machines do not have cash when customers arrive. Furthermore, in some countries, ATM fees compensate ATM who have excess cash in their machines.

[22] Snellman and Viren (2006) argue that ATMs can be used as a strategic tool to entice consumers to use non-cash electronic payment instruments especially when there is market power in the banking sector.

merchants (i.e. increase velocity) or increase overall cash holdings through filling more bank vaults or by lowering the costs of, say, converting paychecks to cash.[23]

The share of self-employed in total employment is a proxy for the proportion of small merchants in an economy. We expect a positive relationship between cash and the self-employed. Smaller merchants are generally slower in adopting newer payment technologies because it takes longer to recover fixed costs and may face higher per-transaction costs. Having a more atomistic employment structure may also be associated with lower levels of tax compliance, which would also involve greater use of cash. The second column of Table 5 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 5 suggests a positive association between the self-employed share and shadow economy size (ρ=0.5). Finally, the opportunity cost of holding cash is measured by the short-term interest rate. As before, all variables are in logarithms, with debit card terminals, ATMs, and bank branches normalized by population.

All Currency

In Table 7, we report results for a number of different econometric specifications. 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. As before, statistical significance at the 5% level or better is indicated by shading.

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/GDP ratio. We also find that the number of bank branches positively affects the

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[23] However, we would expect the demand for cash by merchants would make the relationship between cash and bank branches lean in one direction.

demand for currency, as does the share of self-employed. As expected, the short-term interest rate is negatively related to cash holdings.

Pooled OLS regressions applied to country panel can be problematic for two reasons. First, they do not differentiate between changes within and between countries. Second, they fail to take into account substantial serial correlation within individual countries. Thus, OLS standard errors may be severely biased, leading to incorrect statistical interpretation of the results (Petersen, 2006). Given large differences across countries exemplified, for instance, in Tables 1-3, we use a country fixed effects (FE) specification. As a consequence, we focus on whether within-country changes in the explanatory variables affect country-specific changes in currency demand.

While our coefficient estimates are significantly lower when employing a fixed effect econometric specification, the coefficients on debit terminals, bank branches, and short-term interest rates remain statistically significant. The coefficient on the self-employed share falls from .15 to .02 and is no longer significant. However, in the FE specification, the number of ATMs is negatively correlated with currency stock, with a 10 percent increase in ATMs resulting in a 0.4 percent decrease in the currency to GDP ratio.

The fixed effects approach addresses the second econometric problem – within-country serial correlation – only if country-specific effects are constant over time. A simple analysis of residuals from the FE regression suggests that this is not the case. Consequently, we consider two alternative methods of correcting our estimates. First, we assume that error terms ε_{it} are first-order autocorrelated. Second, we compute clustered standard errors (Rogers, 1993), which allow an arbitrary temporal dependency pattern within each country (Petersen, 2006). We employ clustered standard errors both with the FE estimator and the random-effects (RE)

estimator. The latter augments FE estimates with information on mean differences *across* countries.

The results of these three models, shown in columns (3)-(5) of Table 7, highlight both the importance of accounting for within-country serial correlation and the sensitivity of results to a specific choice of how to do this. In particular, while the effect of debit card terminals on currency demand is negative in all three specifications, it loses statistical significance in a simple FE model with cluster-adjusted standard errors (column 3).[24] Making correlation adjustments also eliminates any identifiable effect of ATM infrastructure as well as that of the self-employed share. Only the short-term interest rates—the cornerstone of money demand models—retains statistical significance in every specification.

In sum, the results of fixed effects estimation differ substantially from those of pooled OLS regressions, particularly if necessary serial correlation adjustments are made. Again, this gives rise to two possibilities—measurement error and model misspecification.

We entertain the first possibility 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 section III), these adjustments may be rather imperfect. And since all of the explanatory variables are domestic, the foreign demand component still left in the dependent variable would obscure the relationship.

Panel B of Table 7 shows the results for the sample of 10 OECD countries that exclude Germany, Switzerland, and the United States. Pooled OLS estimates from the truncated sample are quite similar to those from the full sample. Interestingly, there is now much more persistence in statistical significance of the estimates across specifications. We estimate a consistently negative effect of debit card terminals on currency demand (although it is still weaker than that

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[24] Note that, by construction, making the clustering adjustment by itself leaves FE point estimates unchanged.

estimated with pooled OLS). The share of self-employed is estimated to have a positive effect on currency demand in 3 out of 4 specifications that include country fixed effects (columns 2-4).

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 value 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.

Using ATM-distributed denominations as the "medium-threshold," we define large and small denomination categories as described in section III. 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.[25]

There are several additional benefits from partitioning the currency by denomination. Since the bulk of foreign currency demand is limited to large denominations, we expect the small- and medium-notes demand estimates to be more stable across samples (e.g. panels A and

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[25] 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 the countries in our sample.

B in Table 7). Moreover, by isolating ATM-distributed currencies we attempt to provide a more

precise estimate on what we term the ATM demand factor. As argued above, the effect of ATM

on currency demand is ambiguous and existing empirical studies produce conflicting results.

Finally, if the share of self-employed affects currency demand by facilitating black market

activity, we would expect to identify a relationship for the large denomination category.[26] 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.

The following table summarizes our null hypotheses for denomination-specific models:

	Smaller denominations & coins	ATM-dispensed denominations	Larger denominations
Debit card terminals	**<0**	?	**~0**
ATM access	**~0**	?	**~0**
Bank access	?	**~0**	?
Self-employed	>0 if fixed costs ~0 if tax evasion	?	~0 if fixed costs >0 if tax evasion

The "~0" notation indicates the null of no identifiable effect. A confirmation of this

hypothesis for ATM and bank access variables would serve as additional evidence of the

appropriateness of our currency categorization. That is, ATM density should affect only ATM-

distributed categories, and bank density should have an effect only on bank-distributed

categories.

Table 8 shows the results of fitting a country fixed effects model with cluster-adjusted

standard errors to each denomination category. We chose FE-clustered specification since its

non-parametric formulation gives us a chance to get standard errors right without making strong

assumptions. It is also the only model in which debit terminals had no statistically identifiable

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[26] 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.

effect on total currency demand in the full sample (see panel A of Table 7). Thus, it sets a somewhat higher hurdle for the denomination-specific exercise.

Panel A of Table 8 contains full sample estimates. As expected, debit card terminals have a very strong negative effect on demand for small denominations, but not on that for medium or large denominations. 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 ATM-dispensed 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.

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 U.S.

Panel B of Table 8 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, corroborating the expectation of more stable coefficient estimates across samples.

To check for robustness regarding the dividing lines between the denomination classes, we also run our regressions using DGK's classification. We use 50 British pounds as the cutoff between large and medium. This results in the large denomination category becoming smaller while the medium category becomes larger. The small denomination category is the same as our original one. To compare with DGK, we also report results for a category that combines the medium and small classes.

In panel A of Table 9, we report the results of our regressions. For the large denomination category, the coefficient on short-term interest rate is now significant in the full sample. Because the large classification is narrower, it is more likely that these notes are used as a store of value instead for a medium of exchange. The effect of ATMs is now being picked up in the large, and not the medium denomination category. Debit terminals are estimated to dampen the demand for both small and medium denomination notes, although the effect on medium notes is identified much less precisely. In the category where small and medium denominations are combined, only the coefficient on debit terminals is significant (and negative), suggesting that the medium notes are masking the impact of branches and the self-employed ratio.

For completeness, we show the same set of regressions without Germany, Switzerland, and the United States in panel B of Table 9. For the large denomination category, ATMs are no longer significant but are now significant for the medium category. Interestingly, the estimated ATM sign on the new "medium" specification is now negative. The results for the combined medium and small category in the truncated sample are still negatively related to the number of debit card terminals.

27

VI.   Conclusion

In the 1990s, the usage of debit cards increased rapidly in all of the countries in our sample with the exception of Japan. Our empirical results suggest that the adoption of POS debit terminals by merchants was the key factor in the explosive growth in debit card usage. This suggests that both consumers and merchants generally prefer debit cards to other payment alternatives for certain types of transactions.

Despite the strong growth in the adoption of electronic payment instruments particularly debit cards, cash usage remains significant in most OECD countries suggesting that electronic alternatives have not succeeded in mimicking all the benefits of cash. For example, the anonymity feature of cash is particularly beneficial for tax evasion or illegal transactions and is a key factor for the continued demand for large denomination notes.

As we have noted, the effect of electronic payment instruments on cash usage has been studied by several researchers. However, previous studies have not been able to capture a significant effect of debit cards on cash demand using country panel estimation. A key feature of our econometric model is the ability to disentangle cash's dual roles—store of value and payment media. 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 is lower in value than that dispensed by ATMs. The demand for these notes and coins is driven by purchases requiring merchants to make change. In contrast, electronic substitutes are able to reduce the demand for small denomination notes and coins because no change is required for these transactions. Our regression results suggest that the adoption of debit card terminals has reduced the demand for cash in small denomination notes and coin.

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 will result in a shift from domestic money demand in the country of currency issuance to money demand by residents in other countries. However, only certain OECD currencies are likely to play this role, e.g. U.S. dollar and the euro. The foreign demand for these currencies may decrease as the adoption of electronic instruments proliferates globally.

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Table 1: 2004 Per Capita Payments by Type of Instrument

	Checks	Debit and Credit Cards	Direct Credits	Direct Debits	2004 Total	2001 Total
Austria	1	21	109	75	206	213
Belgium	2	64	76	20	162	151
Canada	43	143	25	19	230	220
Finland	0	112	110	16	238	221
France	66	75	42	41	224	219
Germany	1	27	75	73	177	163
Italy	8	19	18	8	53	50
Japan	1	24	10	NAV	36	31
Netherlands	0	80	78	65	222	214
Sweden	0	109	51	16	177	146
Switzerland	0	49	79	7	135	130
United Kingdom	35	94	44	43	216	203
United States	119	132	17	20	288	275

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

Table 2: Cash Holdings (USD) per Capita and Currency/GDP in 1998

Country	Currency/Capita	Currency/GDP
Finland	613	0.024
United Kingdom	738	0.03
Canada	806	0.039
France	847	0.034
Sweden	1226	0.044
Italy	1251	0.06
Netherlands	1311	0.053
Belgium	1365	0.056
Austria	1677	0.064
United States	1850	0.059
Germany	1875	0.072
Switzerland	3408	0.091
Japan	3620	0.116

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

Table 3: Highest Denomination and ATM notes in 13 OECD countries

| National Currency | Highest Denomination | | Most common ATM note | | October 19, 2000 |
	NCU	US $	NCU	US $	Exchange rate (NCU/$)
Austria Schillings	5,000	$305	100 - 1,000	$6 - $61	16.40
Belgium Francs	10,000	$208	1000	$21	48.08
Canada Dollars	1,000	$658	20	$13	1.52
Finland Markkaa	1,000	$141	100	$14	7.09
France Francs	500	$64	100	$13	7.82
Germany Deutsche Marks	1,000	$429	10 - 100	$4 - $43	2.33
Italy Lire	500,000	$217	10K - 50K	$4 - $22	2307.65
Japan Yen	10,000	$93	10000	$93	107.73
Netherlands Guilders	1,000	$381	100	$38	2.63
Sweden Kronor	1,000	$99	100 - 500	$10 - $49	10.12
Switzerland Francs	1,000	$559	20 - 200	$11 - $112	1.79
United Kingdom Pounds	50	$72	10 - 20	$14 - $29	0.69
United States Dollars	100	$100	20	$20	1.00

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

Table 4: Debit Terminals/10,000 Residents and Debit Cards per Capita in 2003*

Country	Debit Terminals/10000	Debit Cards per Capita
Japan	1.57	3.06
Germany	6.01	1.10
Austria	9.03	1.02
Belgium	10.96	1.33
Switzerland	11.16	0.83
Netherlands	11.53	1.34
Sweden	12.17	0.63
United States	13.23	0.89
Canada	14.24	1.17
United Kingdom	14.54	1.06
Italy	16.14	0.49
France	16.63	0.74
Finland	17.66	0.79

*For Canada, 2000 figures are taken because more recent figures are not available

Source: CPSS Red and ECB Blue Books

Table 5: Self-employed to Total Employment Ratio

Country	Self-employed ratio (1998)	Shadow Economy as % of official GDP (1999)
France	7.70	15.2
United States	7.94	8.7
Sweden	8.33	19.2
Germany	10.19	16
Finland	12.18	18.1
United Kingdom	12.88	12.7
Switzerland	13.61	8.6
Netherlands	14.82	13.1
Canada	17.26	16
Belgium	17.40	22.2
Japan	17.60	11.2
Austria	20.76	9.8
Italy	34.47	27.1

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

Table 6: Debit Card Adoption

Dependent variable: *log* (debit card volume/pop)	1	2	3
log(Debit Card Number/pop)	0.67		0.12
	4.81		-0.53
log(Debit Card Terminals/pop)		0.99	0.91
		7.25	5.13
log(ATM/pop)	1.32	0.25	0.25
	3.19	1.67	1.33
log(Checkvol/pop)	-0.51	0	-0.03
	(-3.72)	0.02	(-0.23)
log(Bank branches/pop)	1.78	0.17	0.25
	1.64	(0..29)	0.45
log(Ratio of self-employed)	38.58	9.56	14.27
	2.25	-1.03	1.29
log(Short-term interest rate)	-13.9	-4.78	-4.97
	(-2.81)	(-2.04)	(-1.88)
constant	-12.51	-5.94	-7.06
N	182	187	182
Goodness-of-fit measure	0.94	0.97	0.97

Table 7: Various Econometric Models of Simple Currency Demand

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

Dependent variable: *log* (currency stock / GDP ratio)	Pooled OLS	Fixed Effects (FE)	Corrections for country-level serial correlation		
			FE with cluster-adjusted SE	FE with AR(1) errors	RE with cluster-adjusted SE
log(Debit terminals/pop)	-0.12	-0.02	-0.02	-0.05	-0.03
	(-10.3)	(-2.19)	(-1.43)	(-3.47)	(-2.32)
log(ATMs/pop)	-0.05	-0.04	-0.04	0.06	-0.01
	(-1.3)	(-2.13)	(-1.34)	(1.69)	(-0.29)
log(Bank branches/pop)	0.46	0.30	0.30	0.11	0.36
	(9.52)	(5.78)	(4.17)	(1.58)	(5.68)
log(Ratio of self-employed)	0.15	0.02	0.02	0.14	0.14
	(3.77)	(0.32)	(0.15)	(1.02)	(1.26)
log(Short-term interest rate)	-0.30	-0.07	-0.07	-0.03	-0.09
	(-10.5)	(-4.27)	(-3.18)	(-2.09)	(-4.05)
Y2K dummy	0.01	0.04	0.04	0.09	0.04
	(0.19)	(1.3)	(1.8)	(7.23)	(1.86)
constant	2.04	1.82	1.82	1.46	1.61
N	169	169	169	156	169
	adj. R^2	within R^2	within R^2	within R^2	overall R^2
Goodness-of-fit measure	0.67	0.31	0.31	0.36	0.57

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: *log* (currency stock / GDP ratio)	Pooled OLS	Fixed Effects (FE)	Corrections for country-level serial correlation		
			FE with cluster-adjusted SE	FE with AR(1) errors	RE with cluster-adjusted SE
log(Debit terminals/pop)	-0.12	-0.02	-0.02	-0.07	-0.04
	(-8.45)	(-2.68)	(-2.04)	(-4.12)	(-2.79)
log(ATMs/pop)	-0.13	-0.03	-0.03	0.04	-0.01
	(-3.07)	(-1.78)	(-1.09)	(1.11)	(-0.24)
log(Bank branches/pop)	0.26	0.35	0.35	0.23	0.35
	(3.56)	(7.4)	(4.51)	(2.63)	(4.42)
log(Ratio of self-employed)	0.23	0.22	0.22	0.33	0.33
	(4.89)	(2.13)	(1.00)	(2.08)	(2.31)
log(Short-term interest rate)	-0.31	-0.09	-0.09	-0.03	-0.12
	(-9.67)	(-4.89)	(-4.36)	(-2.05)	(-4.64)
Y2K dummy	0.00	0.04	0.04	0.07	0.03
	(-0.02)	(1.2)	(1.71)	(5.47)	(1.63)
constant	1.61	1.33	1.33	1.01	1.11
N	128	128	128	118	128
	adj. R^2	within R^2	within R^2	within R^2	overall R^2
Goodness-of-fit measure	0.71	0.43	0.43	0.39	0.52

Table 8: Denomination-specific currency demand: FE model with cluster-adjusted SEs

Original 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   note: same as alt.

	logarithm of		
Dependent variable:	Large/GDP	Medium/GDP	Small/GDP
log(Debit terminals/pop)	0.00	0.03	-0.04
	(-0.16)	(0.88)	(-3.69)
log(ATMs/pop)	-0.03	-0.24	0.00
	(-0.29)	(-2.25)	(0)
log(Bank branches/pop)	0.42	0.21	0.27
	(2.53)	(1.04)	(2.91)
log(Ratio of self-employed)	-0.34	0.29	0.32
	(-1.12)	(1.3)	(3.16)
log(Short-term interest rate)	-0.06	-0.04	-0.02
	(-1.65)	(-1.57)	(-1.46)
Y2K dummy	0.02	0.02	0.00
	(0.34)	(0.73)	(-0.12)
constant	-2.57	-4.95	-5.81
N	169	169	169
	within R^2	within R^2	within R^2
Goodness-of-fit measure	0.07	0.21	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.

	logarithm of		
Dependent variable:	Large/GDP	Medium/GDP	Small/GDP
log(Debit terminals/pop)	-0.03	0.03	-0.04
	(-1.13)	(1.15)	(-3.21)
log(ATMs/pop)	0.05	-0.27	0.00
	(0.78)	(-2.75)	(0.09)
log(Bank branches/pop)	0.47	0.26	0.30
	(2.56)	(1.29)	(2.97)
log(Ratio of self-employed)	0.22	0.24	0.40
	(0.88)	(0.54)	(2.69)
log(Short-term interest rate)	-0.13	-0.03	-0.03
	(-5.24)	(-0.76)	(-1.59)
Y2K dummy	0.05	0.00	-0.01
	(1.63)	(-0.01)	(-0.48)
constant	-3.81	-5.00	-6.07
N	128	128	128
	adj. R^2	within R^2	within R^2
Goodness-of-fit measure	0.26	0.46	0.64

Table 9: Denomination-specific currency demand: FE model with cluster-adjusted SEs

Alternative classification	*Large: greater than 50 GBP*
	Medium: ATM-dispensed notes if less than 50GBP
	Low: less than ATM-dispensed notes+coin

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

	logarithm of			
Dependent variable:	Large/GDP	Medium/GDP	Small/GDP	(Medium+Small)/GDP
log(Debit terminals/pop)	0.06	-0.06	-0.04	-0.06
	(1.44)	(-2.01)	(-3.69)	(-2.3)
log(ATMs/pop)	-0.26	0.12	0.00	0.09
	(-1.99)	(1.4)	(0)	(1.34)
log(Bank branches/pop)	0.56	-0.18	0.27	-0.10
	(2.31)	(-0.95)	(2.91)	(-0.64)
log(Ratio of self-employed)	-0.19	-0.04	0.32	0.04
	(-0.53)	(-0.19)	(3.16)	(0.21)
log(Short-term interest rate)	-0.09	0.02	-0.02	0.02
	(-2.2)	(0.62)	(-1.46)	(0.77)
Y2K dummy	0.04	0.04	0.00	0.03
	(0.65)	(1.73)	(-0.12)	(1.62)
constant	-3.42	-3.78	-5.81	-3.66
N	169	169	169	169
	within R^2	within R^2	within R^2	within R^2
Goodness-of-fit measure	0.11	0.21	0.66	0.26

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.

	logarithm of			
Dependent variable:	Large/GDP	Medium/GDP	Small/GDP	(Medium+Small)/GDP
log(Debit terminals/pop)	0.04	-0.07	-0.04	-0.06
	(0.93)	(-2.58)	(-3.21)	(-2.89)
log(ATMs/pop)	-0.22	0.15	0.00	0.12
	(-1.86)	(2.18)	(0.09)	(2.05)
log(Bank branches/pop)	0.60	-0.17	0.30	-0.10
	(2.27)	(-0.91)	(2.97)	(-0.59)
log(Ratio of self-employed)	0.26	0.36	0.40	0.38
	(0.71)	(1.58)	(2.69)	(2.07)
log(Short-term interest rate)	-0.13	-0.03	-0.03	-0.02
	(-4.05)	(-1.13)	(-1.59)	(-0.97)
Y2K dummy	0.10	0.01	-0.01	0.00
	(1.62)	(0.3)	(-0.48)	(0.24)
constant	-4.53	-4.82	-6.07	-4.53
N	128	128	128	128
	within R^2	within R^2	within R^2	within R^2
Goodness-of-fit measure	0.27	0.26	0.64	0.28

Figure 1: Per Capita Debit Card Volume

Legend:
Austria, Belgium, Canada, Finland, France
Germany, Italy, Japan, Netherlands, Sweden
Switzerland, United Kingdom, United States
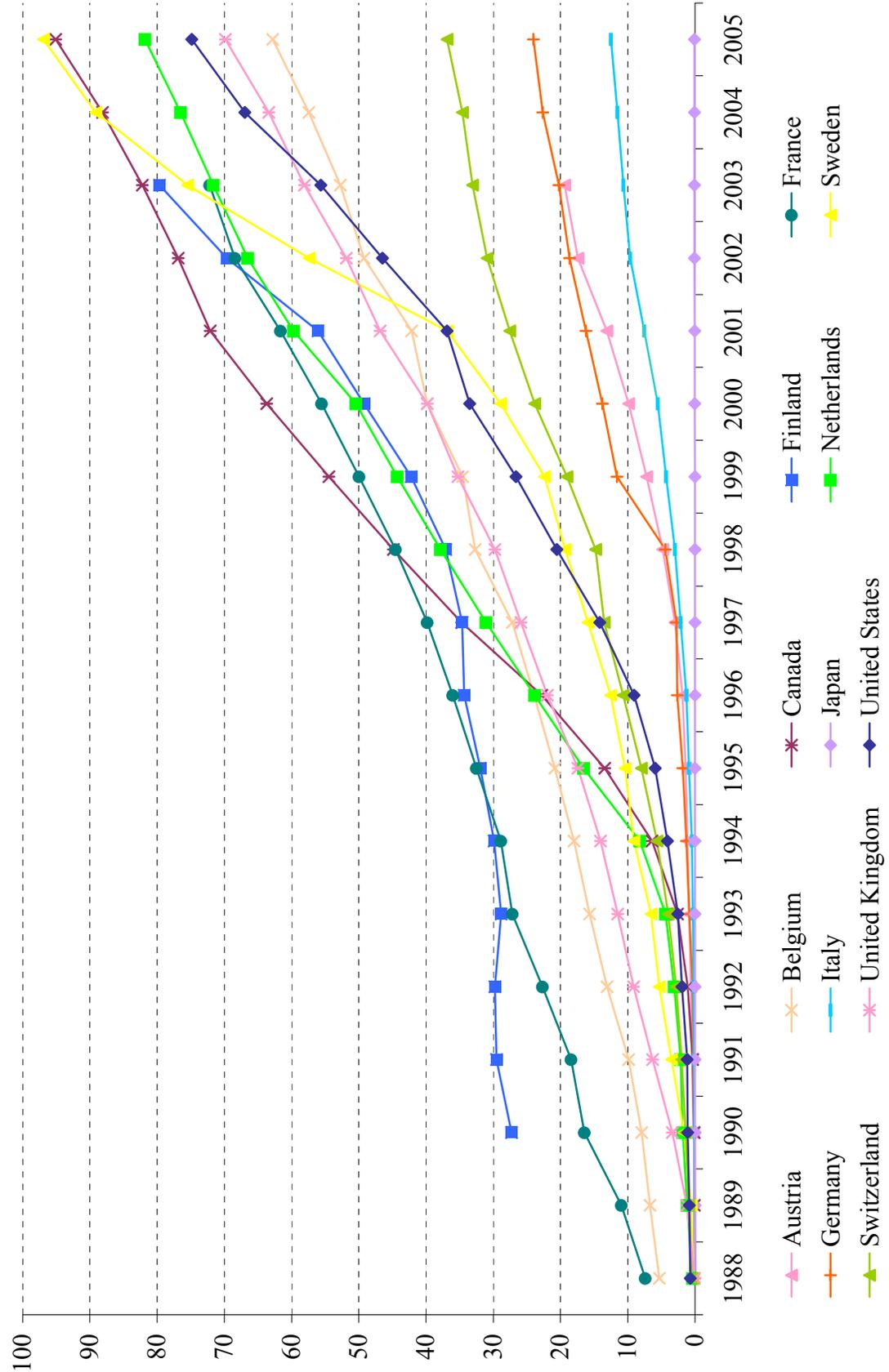
Figure 2: Currency Holdings/GDP
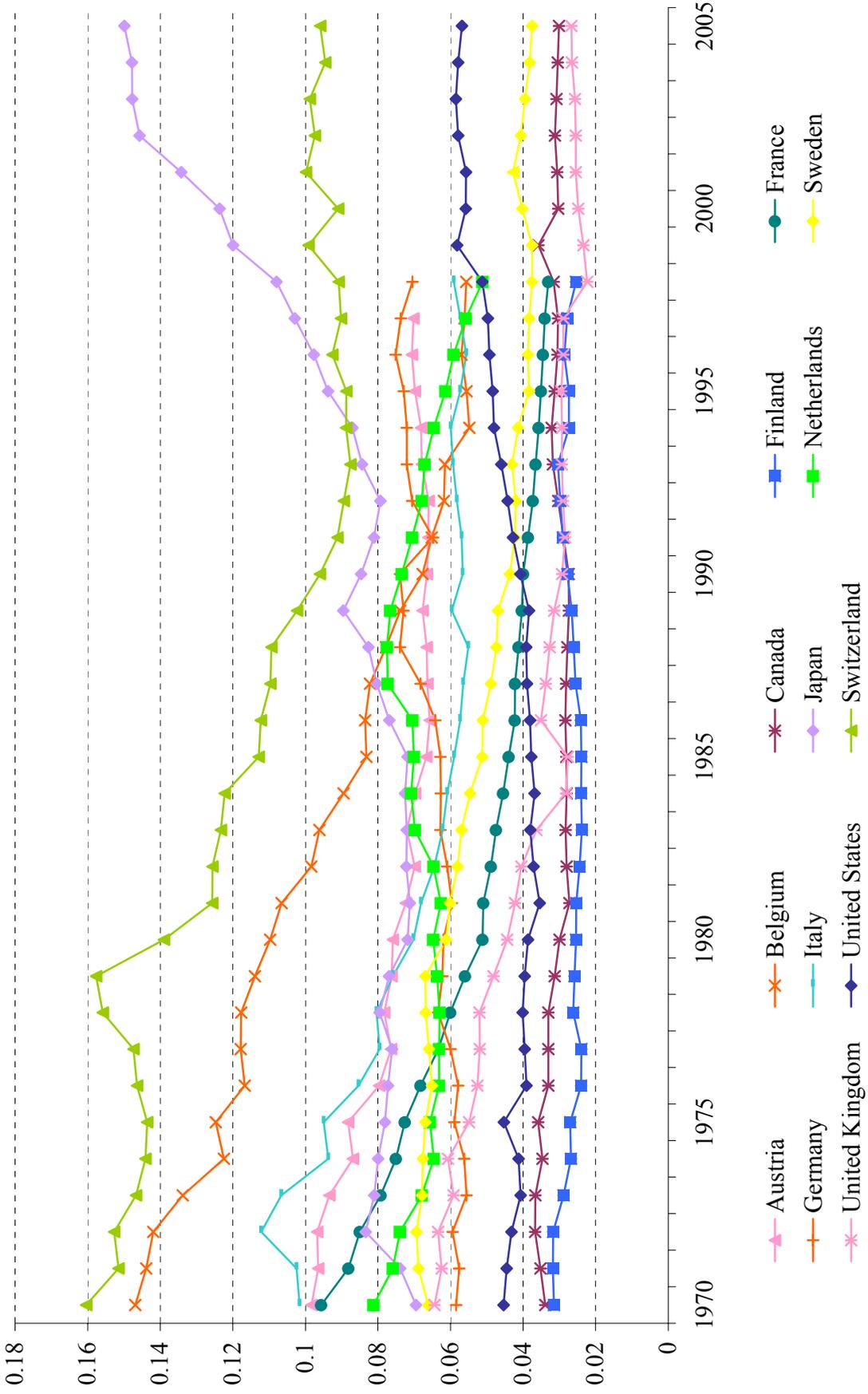
Figure 3: Currency/GDP and Debit Terminals/1000 Individuals (1998)
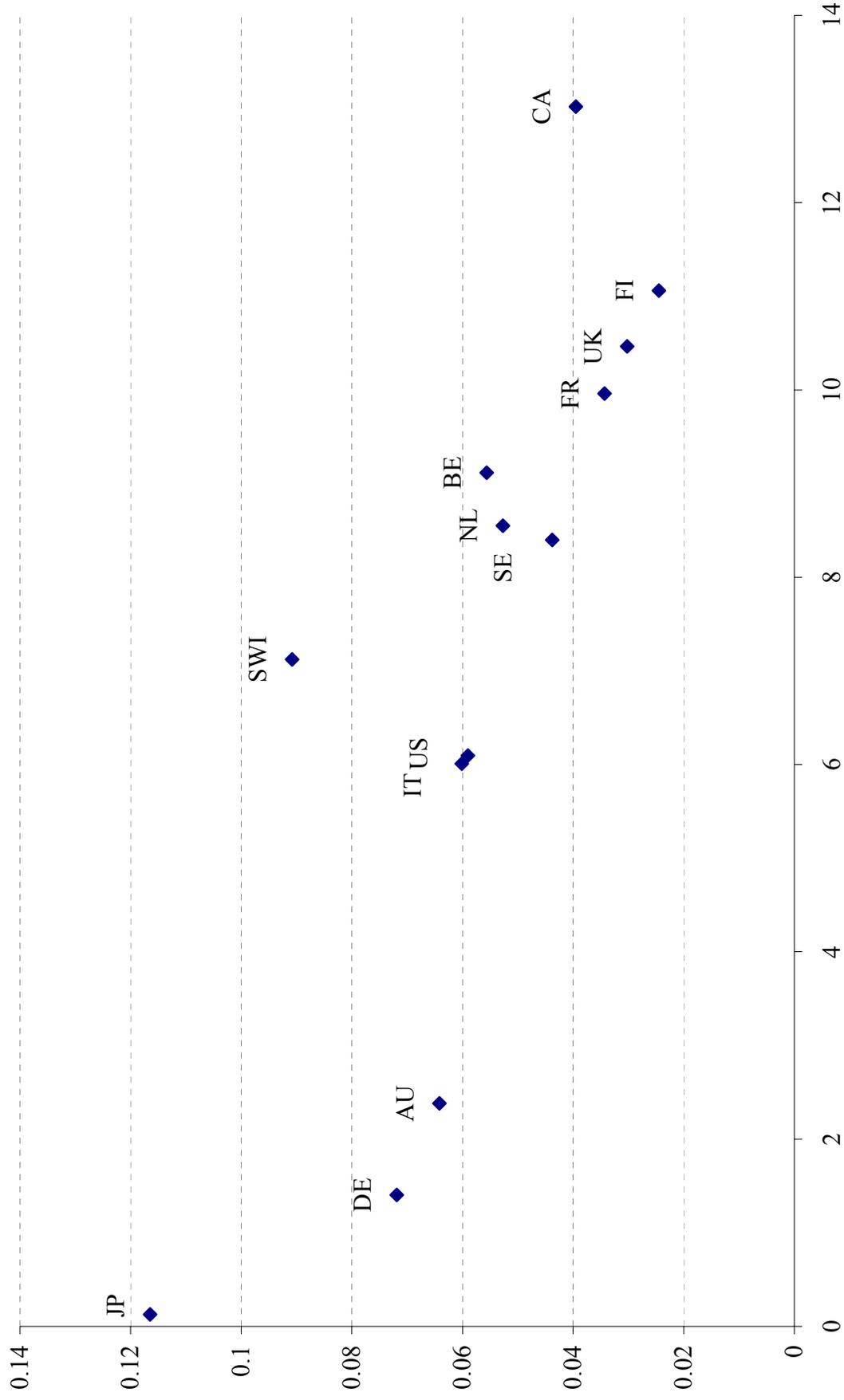
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