Digital Payments Adoption and the Demand for Cash: New International Evidence

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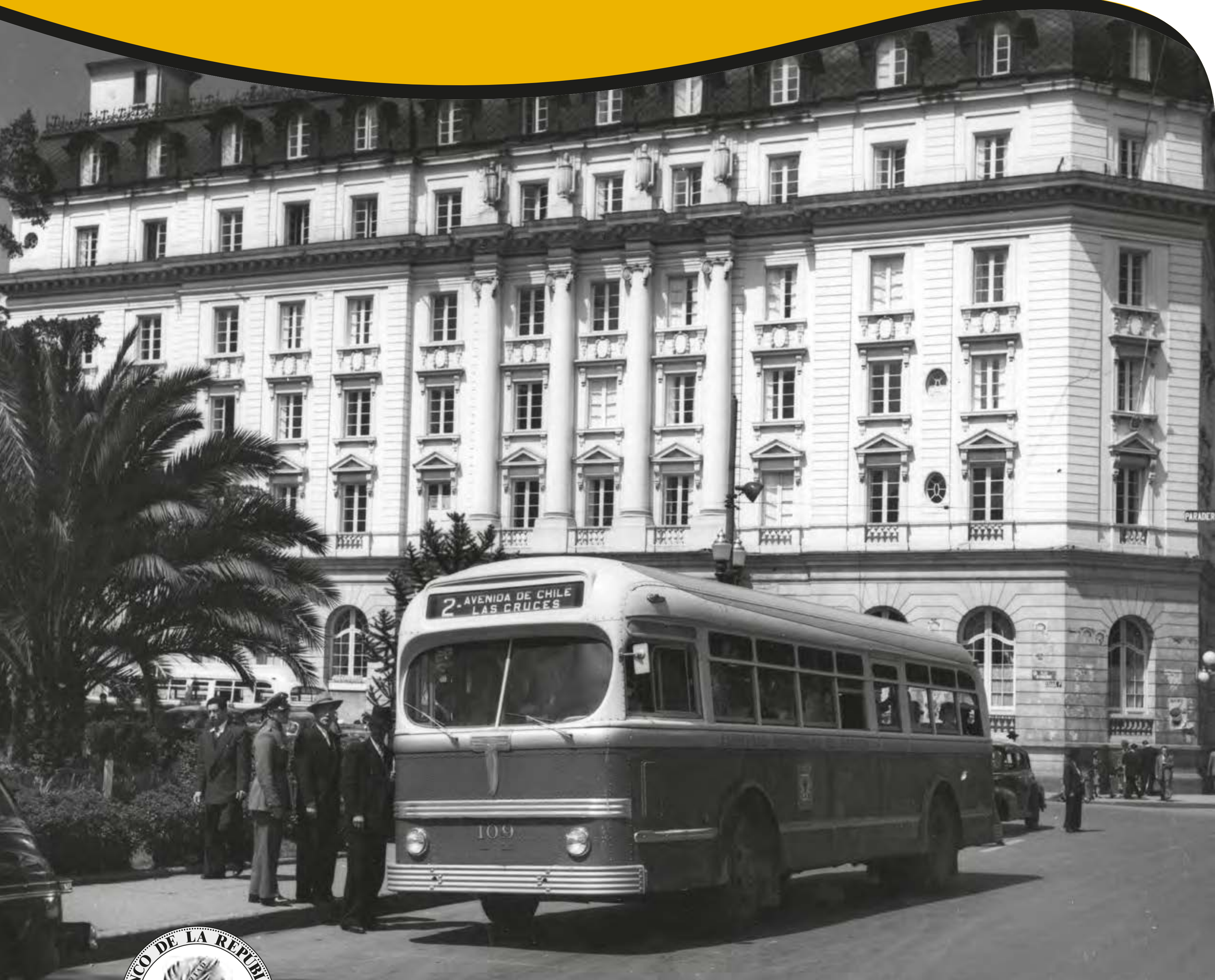

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Abstract

Even though the levels and growth rates of adoption of digital payments have reached significant figures in the recent past, the demand for cash continues to grow in both developed and developing economies across the world. This puzzle has found only partial explanations in the previous empirical literature. We bring further and more conclusive evidence that the adoption of digital payments indeed reduces the demand for cash. Yet, economic growth and lower interest rates as well as positive trends in the demand for large denomination banknotes, not explained by traditional factors, still dominate the overall growth in the demand for cash.

JEL classification: E41, E42, E47, E58.
Keywords: money demand; digital payments; cash; denominational structure; panel data.

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Adopción de pagos digitales y la demanda por efectivo: nueva evidencia internacional

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Abstract

Aun cuando los niveles y tasas de crecimiento de la adopción de pagos digitales han alcanzado valores significativos en el pasado reciente, la demanda por efectivo continua creciente tanto en economías desarrolladas como en desarrollo alrededor del mundo. Este acertijo solo ha encontrado explicaciones parciales en la literatura previa. Nosotros proveemos evidencia adicional y más concluyente de que la adopción de pagos digitales reduce la demanda por efectivo. Sin embargo, el crecimiento económico y las menores tasas de interés, así como las tendencias positivas en la demanda por billetes de alta denominación, no explicadas por variables tradicionales, aun dominan el crecimiento agregado en la demanda de efectivo.

Clasificación JEL: E41, E42, E47, E58.
Palabras clave: demanda de dinero; pagos digitales; efectivo, estructura denominacional; datos panel.

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1 Introduction

With the rise of new alternatives to make payments, much has been said about the imminent disappearance of cash. Nevertheless, although the use of electronic payments has increased at accelerated rates in both developed and developing economies, cash keeps being printed because the public continues to demand it. Indeed, as reported by Esselink and Hernández (2017), 79% of the volume and 54% of the value of payments at POS in the euro area are made using this instrument.

Likewise, Table 1 shows that the demand for cash in developed economies like Japan, Singapore and the United States is high, in per capita terms, and it has been growing in the recent past in spite of high rates of growth and levels of usage of digital payment instruments. A similar situation is observed among developing economies, such as Bulgaria, Colombia, Czech Republic, Mexico, Poland, Romania and South Africa, that hold growing cash balances per capita while having even greater growth rates in digital payments. There are, however, exceptions such as Norway and Sweden, where cash is losing ground and digital payment usage is highest.

Country	Cash holdings per capita, 2015 (2011 purchasing power parity dollars)	Cash holdings per capita mean annual growth rate, 2011-2015 (%)	Electronic payments per capita, 2015	Electronic payments mean annual growth rate, 2010-2015 (%)
Australia	2,060	2.78	410	7.48
Brazil	560	-0.19	135	8.17
Bulgaria	2,435	7.54	39	39.98
Canada	1,636	2.92	317	4.61
Colombia	908	8.42	12	10.66
Czech Republic	3,390	3.93	208	23.07
Denmark	1,557	0.72	367	7.37
Hungary	3,138	10.13	106	4.30
Japan	7,272	3.50	NA	NA
Mexico	1,138	7.06	28	11.90
Norway	1,023	-3.36	486	5.61
Poland	2,292	8.19	129	15.84
Romania	1,534	9.20	26	11.26
Russian Federation	2,588	-2.19	88	28.31
Singapore	7,725	7.09	132	6.16
South Africa	615	4.84	69	10.95
Sweden	764	-9.73	428	6.92
Turkey	1,255	8.99	NA	NA
United Kingdom	1,431	2.54	337	6.27
United States	4,163	5.17	383	6.73
EU	3,737	4.64	197	3.58

Note: cash holdings for most European countries are only available before the introduction of the euro in the end of the nineties decade.

Source: Global Payment Systems Survey, The World Bank; International Monetary Fund.

Table 1: Cash holdings and electronic payments, levels and mean annual growth

From these stylized facts it is valid to ask why, even with the increased use of new payment methods, cash usage does not fade away for most countries. This is an important question for central banks given their need to understand trends in cash demand for their decisions about issuance and distribution of banknotes and coins. It is also important because governments are encouraging the use of electronic payment instruments to obtain efficiency gains in the payment system, higher levels of financial inclusion and better financial intermediation of funds stored in cash (Buku and Meredith (2013); Donovan (2012)). Finally, some authors argue that restricting the use of cash, by phasing out large value banknotes and capping cash transactions, among other interventions, may reduce activities in the underground economy such as tax evasion, drug trade, illegal immigration and money laundering (Immordino and Russo (2017); Rogoff (2014); Rogoff (2016)).

The empirical literature on money demand has traditionally and consistently found a positive effect of income and a negative impact of interest rates over different measures of monetary aggregates (Knell and Stix (2006)). When attention is restricted to narrow definitions of money, as in the case of cash demand, estimations have confirmed these relations and the importance of other factors such as financial innovations and the shadow economy (Alvarez and Lippi (2009); Herwartz et al. (2016)).

More recently, several papers have looked into the impact of payment innovations on the demand for cash. Through a generalized Baumol-Tobin framework, Attanasio et al. (2002) find that individuals with access to ATM cards exhibit higher interest rate elasticities, compared to households not holding this type of cards. Lippi and Secchi (2009) use ATM and bank branch densities to identify the impact that cash withdrawal technologies have on money demand, revealing a decreasing level of cash holdings as more free cash withdrawal opportunities are available for households.

Using microdata, Fung et al. (2014) analyze the impact that stored-value and contactless credit cards have on cash usage based on data from a payments survey applied to Canadian households in 2009 and propensity score matching. Their results indicate that payment innovations reduce the share of cash, both in the volume and in the total value of payments. In contrast, Chen et al. (2017) find no significant effects of the introduction of contactless cards on cash usage amongst Canadian households when addressing unobserved heterogeneity, based on three years of longitudinal data (2010, 2011 and 2012). Likewise, Fujiki and Tanaka (2009) focus on the influence of electronic money adoption in households' demand for currency using a 2007 survey dataset for Japan, and conclude that average cash balances do not decrease with the use of this new payment technology.

The literature has also proposed different relations between cash demand and its determinants depending on the value of banknotes and coins in circulation. Drehmann et al. (2002) study currency demand by denomination for a sample of OECD countries. They find that the demand for cash, at the aggregate level and for large and small value banknotes, depends positively on economic activity and inversely on nominal interest rates but find no evidence of reductions in cash balances due to advancements in digital payments.

More recently, Amromin and Chakravorti (2009) estimate the demand for large and small value denominations as a percentage of GDP for 13 OECD countries. They show that the demand for large value denominations is affected by changes in interest rates but not by the use of alternative digital payment technologies (proxied by electronic funds transfer at the point of sale -EFTPOS- terminals). In contrast, the demand for small value denominations falls as the adoption of digital payments increases. The work by Bech et al. (2018) also underscores that the data on currency demand shows strong growth in most developed and developing countries in spite of strong adoption of digital payments. However, their estimations only include the traditional factors that may affect large and small value currency demand, without exploring the impact of digital payments.

We study the demand for cash following the considerations of Drehmann et al. (2002) and Amromin and Chakravorti (2009). We differentiate the demands for large (above USD 31 in 2011 constant purchasing-power-parity -PPP- dollars) and small value denominations (between USD 31 and USD 1 in 2011-PPP dollars). We consider traditional determinants like income (GDP) and the opportunity cost of cash (short-term interest rates). We also include measures of innovations in payments markets such as the development of ATM networks, which impacts the cost of accessing cash, and the depth of acceptance of digital payments based on the EFTPOS networks by country. Unemployment rates are used as proxies for cyclical levels of self-employment and labor informality.

Our contributions to the literature are threefold. First, the estimations are based on a macroeconomic panel dataset covering 54 developed and developing economies, from the early 1990s to 2014. This allow us to observe established markets where digital payments have been around for more than 60 years, jointly with economies where payment innovations are at early stages of adoption but are already showing accelerated growth rates. Through this novelty, we provide evidence of the impact of digital payments adoption on the demand for cash that contrast with the previous literature. Second, we adjust our measures of large and small value denominations in circulation by taking into account changes in purchasing power and upgrades in the denominational structure of each country. Third, we use an instrumental variables approach to control for possible endogeneity issues associated with two-way relationships of variables such as the ATM and EFTPOS networks.

We find significant positive effects of GDP and the ATM networks on the aggregate demand for cash. In contrast, higher interest rates and deeper penetration of EFTPOS networks reduce the demand for cash. The same relations are found when considering only the demand for large value banknotes, although in this case the statistical significance of the coefficients associated with each variable is stronger. In contrast, the demand for small value banknotes is not only negatively associated with short-term interest rates, but also with ATM networks, with no evidence that broader acceptance of digital payments (EFTPOS networks) significantly impact the demand for small value denominations. Our results contrast with those found in previous literature and are aligned with the recent microeconometric studies which find that payment instruments like debit and credit cards are strongest substitutes of cash at transactions above the USD 15-20 range, precisely where large value banknotes are used in payments (Arango-Arango et al. (2015b); Arango-Arango et al. (2018)).

We estimate that during the period 2011-2014 the average increase in the EFTPOS networks had a negative effect of 8.2% in the total demand for cash. This effect is almost equal to the combine positive effect on the demand for cash due to GDP growth (3.4%), ATM network expansion (3.0 %) and interest rates decline (1.43 %). This result suggests that the average demand for currency in the countires of our sample would have remaiend relatively constant, except for the fact that the demand for cash shows strong positive trends, not explained by traditional factors modeling currency demand (the transactions motive), in particular driven by the demand for high denomination banknotes.

The rest of the paper is organized as follows. Section two presents the econometric strategy and makes a detail description of the dataset. Section three presents the results and section four concludes.

2 The econometric modeling of cash demand

Different alternatives are considered to model the demand for cash, depending on the currency aggregate used as the dependent variable and how the EFTPOS network variable is included in the estimation. We model currency demand as a function of economic activity and interest rates, together with variables that measure innovations in payment systems infrastructures and other variables that proxy for informality levels like the unemployment rate (Chen et al. (2017); Drehmann et al. (2002); Amromin and Chakravorti (2009)).

For the first specification, total currency is modeled as:

$$CASH_{it} = \beta_0 + \beta_1 GDP_{it} + \beta_2 R_{it} + \beta_3 ATM_{it} + \beta_4 UNEMP_{it} + \beta_5 t + \gamma_1 EFTPOS_{it} + \epsilon_{it}, \quad (1)$$

where $CASH$ is the natural logarithm of the value, in 2011-PPP dollars, of currency outside the issuing institution, held by resident and nonresident sectors (Cartas and Harutyunyan (2017)); GDP is the natural logarithm of the gross domestic product, also expressed in 2011-PPP dollars; R is the short-term nominal interest rate[1]; ATM is the number of automatic teller machines per 100,000 people; $UNEMP$ is the unemployment rate; t is a linear time trend included to model the long term evolution of currency demand; $EFTPOS$ is the number of terminals for electronic funds transfer

[1]Rate paid by commercial or similar banks for demand, time, or savings deposits. Source: International Monetary Fund.

at point of sale per 100,000 people[2] and ϵ is the corresponding stochastic disturbance, which is assumed to be the sum of a fixed effect μ_i and an i.i.d. residual ω_{it}. The sub-indexes i and t represent countries and years, respectively.[3]

Two complementary models are derived from equation 1 to explore possible non-linearities existing in the relationship between EFTPOS and currency. First, we introduce a simple quadratic specification by adding the term $\gamma_2 EFTPOS^2_{it}$. Second, we introduce a spline specification by adding, in accordance with model fit, some or all of the terms in $\sum_j \gamma_j \delta_j (EFTPOS_{it} - EFTPOS_{q_j})$, where $EFTPOS_{q_j}$ is the jth quartile calculated from the empirical distribution of the $EFTPOS$ variable and δ_j is dummy variable that equals 1 if $EFTPOS_{it} \geq EFTPOS_{q_j}$, and 0 otherwise, with $j = 2, 3, 4$.

Possible non-linearities in the impact that payment innovations may have in the demand for currency could arise from the nature of the adoption process of such innovations. In particular, it is well documented that the adoption of technological innovations move though different phases, starting with the slow undertaking by early adopters but accelerating as it is taken by the masses, until it reaches a saturation or maturity stage. This process may induce non-linear effects on how economies reduce their demand for cash balances. At early stages, the reduction may not be substantial as the high uncertainty about the acceptance of digital payment instruments may induce a

[2]We avoid including variables related to transactions in debit or credit cards as the decisions on cash (and cash holdings) and digital payments usage are part of the same optimization problem consumers face when deciding how to make their spending. This simultaneity in the choices between using cash and digital payments may lead to endogeneity issues in the econometric estimation. Here we follow Amromin and Chakravorti (2009) and include the EFTPOS network which reflects the acceptance decisions by merchants and is a prerequisite for consumers to be able to use their digital payment instruments.

[3]Equation (1) can be derived as in Huynh et al. (2014). Consumers hold money balances M and cards to reduce the time cost of making transactions, which is the product of time spent, τ, and the opportunity cost of time w. However, holding cash implies the cost of forgoing returns from assets yielding a nominal interest rate R. The consumer thus minimizes the shopping transaction costs:

$$\begin{aligned} &\min_{M} \qquad \tau w + RM \\ &\text{Subject to:} \quad \tau = \left(\tfrac{c}{M}\right)^{\beta} e^{\gamma EFTPOS}, \end{aligned}$$

where the time spent paying, τ, is assumed to be increasing in consumption c, and decreasing in M and in the network of $EFTPOS$ available to the consumer.

Solving for M, money demand is:

$$M = \left(\frac{w\beta e^{\gamma EFTPOS}}{R}\right)^{\frac{1}{1+\beta}} c^{\frac{\beta}{1+\beta}}.$$

Taking logs yields a simplified form of equation (1):

$$\ln M = \tilde{\alpha} + \tilde{\beta} c + \tilde{\gamma} EFTPOS + \tilde{\delta} R,$$

where $\alpha = (ln(w\tilde{\beta}))/(1+\beta)$, $\tilde{\beta} == \beta/(1+\beta)$, $\tilde{\gamma} = \gamma/(1+\beta)$ and $\tilde{\delta} = 1/(1+\beta)$.

precautionary demand for cash among consumers (Huynh et al. (2014); Eschelbach and Schmidt (2013)). However, as acceptance increases there may be a tipping point where consumers feel it is safe to reduce cash balances, as the risk of incurring high costs to get cash in case their digital payment alternatives are not accepted falls significantly.

The next two specifications follow the recent literature on the demand for cash balances (Amromin and Chakravorti (2009); Drehmann et al. (2002)). This literature emphasizes the different functions of money, arguing that large value banknotes tend to serve more as store of value whereas small value banknotes better serve as a means of payment. Therefore, there is the expectation that payment innovations would have a stronger impact on the demand for the latter.

We propose an alternative hypothesis and argue that both large and small value banknotes are held with the expectation that they eventually will be used as means of payment. A key difference between large and small denominations is that large denominations are more suitable for transactions of high value, which are made less frequently, compared with those transactions served by small value denominations. Under this approach, it is the large value denominations which may be more prone to be substituted with alternative digital payment instruments that are safer and more convenient to use than cash (Arango-Arango et al. (2015a); Arango-Arango et al. (2015b)).

With these hypothesis in mind, we estimate the following models, dividing total currency in large and small value denominations:

$$CASH^l_{it} = \beta^l_0 + \beta^l_1 GDP_{it} + \beta^l_2 R_{it} + \beta^l_3 ATM_{it} + \beta^l_4 UNEMP_{it} + \beta^l_5 t + \gamma^l_1 EFTPOS_{it} + \epsilon^l_{it} \quad (2)$$

and

$$CASH^s_{it} = \beta^s_0 + \beta^s_1 GDP_{it} + \beta^s_2 R_{it} + \beta^s_3 ATM_{it} + \beta^s_4 UNEMP_{it} + \beta^s_5 t + \gamma^s_1 EFTPOS_{it} + \epsilon^s_{it}, \quad (3)$$

where the superscript l stands for large value denominations and $CASH^l$ is the natural logarithm of the value in circulation, in 2011-PPP dollars, of all currency denominations with a face value above 31 2011-PPP dollars.[4] Likewise, the superscript s stands for small value currency denominations, and $CASH^s$ equals the natural logarithm of the value in circulation, in 2011-PPP dollars, of all currency denominations with a face value below 31 2011-PPP dollars and above USD 1 2011-PPP dollars.

Again, to incorporate non-linear effects in the relationship between the EFTPOS variable and large (small) denomination aggregates, equations 2 and 3 are further extended by adding $\gamma^{type}_2 EFTPOS^2_{it}$ or, alternatively, some or all of the spline terms in

[4]This is similar to the strategy used in Drehmann et al. (2002), where large (small) banknotes are those whose value is above (bellow) 50 British pounds.

$\sum_j \gamma_s^{type}\delta_s^{type}(EFTPOS_{it} - EFTPOS_{q_s})$, with $j = 2, 3, 4$ and $type = h, l$. The rest of the variables and sub-indexes work as in the currency demand equation 1.

The 31 and 1 2011-PPP dollar thresholds for the $CASH^l$ and $CASH^s$ variables are defined taking the United States as the reference country to guarantee that the large value currency aggregate for this particular country always includes USD 100 and 50 banknotes, while the small value currency aggregate is made exclusively from USD 20, 10, 5 and 1 banknotes and USD 1 coins. For other countries, especially those with high inflation rates, large and small value currency aggregates may experience "jumps". This can happen for two reasons, both due to the loss of purchasing power of the denominational structure. First, a specific denomination can turn from a value above 31 2011-PPP dollars to a value below this threshold, making it change from the large value denomination aggregate to the small value denomination counterpart. Second, "jumps" may happed because of the issuance of a new denomination.

As an example, Bulgaria faced a hyperinflation period in the nineties, with rates ranging from 73% in 1993 to an outstanding 1,058% in 1997, that affected its denominational structure: in 1993 the two greatest currency denominations were 500 and 200 levs, but that situation changed in 1994 when the 2,000 and 1,000 levs banknotes were introduced, in 1996 with the appearance of the 10,000 and 5,000 levs bills, and again in 1997 when the 50,000 levs banknote was issued. The effects of all these changes in the denominational structure of Bulgaria are represented in Figure 1, where large and small value currency definitions are shown in 2011-PPP dollars. The big rise observed for the large value denomination aggregate in 1995 obeys to a strong increase in the emission of 2,000 and 1,000 levs notes, while the decline in 1996 is due to the high inflation rate for that year (121%). Also, the increase observed in 1997 corresponds to the emission of the new 5,000 levs bill. The situation is very similar for small value currency, but in this case the inflation of 1997 could not be countered by the inclusion of new denominations in the aggregate.

To tackle the "jumps" we implement different strategies. First, dummy variables are included in the estimation to account for most of the "jumps" observed in the longitudinal series by country. Second, given the instability of the optimization process used for estimation as a result of the large amount of dummies, we used interpolation for some countries around the "jumps" to gain parsimony in the number of parameters to estimate. Finally, we dropped the most extreme "jumps" (but not the country) as a robustness check for how influential these events may be on our estimates.

Equations 1, 2 and 3 differ from those presented in Amromin and Chakravorti (2009), where money demand is modeled using the natural logarithm of the monetary aggregates to GDP ratios as dependent variables. This specification imposes a restriction on the way economic activity affects money demand by assuming a unitary elasticity. We include this specification, for total currency as well as for large and small value currency, in our set of estimates for comparison with previous literature and to show that relaxing the assumption reveals GDP elasticities that are significantly different from one and that the restriction may impose some bias in the estimates of other parameters.

Unobserved factors like consumer preferences can simultaneously influence the de-

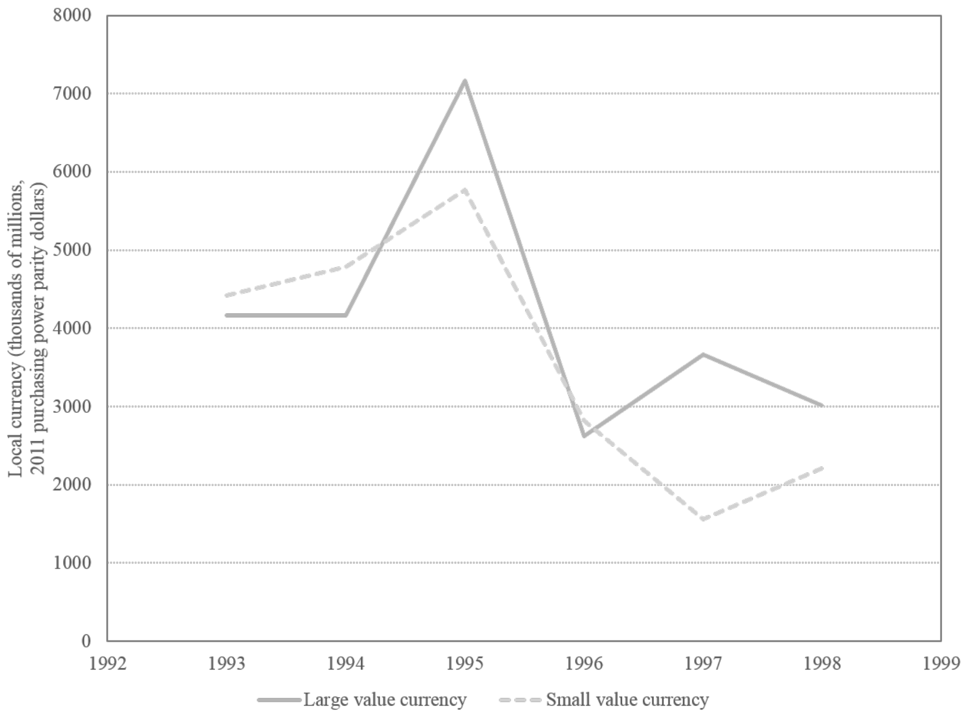


Figure 1: Jumps in large and small value currency

velopment of ATM networks and the demand for cash. There is also the possibility of a two-way causality between developments in ATM networks and cash demand. Hence, we introduce instrumental variable techniques to address the potential inconsistency issues that may arise from the violation of the orthogonality conditions of our regressors. We use telephone land lines, GDP growth and mean annual temperatures as instruments. Telephone lines are a good instrument for our technological variables as they are required for the operation of ATM as well as the EFTPOS networks. Also, GDP growth is hardly related to unobserved factors that may shift the demand for cash, beyond those captured by variables already included such as GDP, the interest rate and unemployment,[5] but would create incentives for the development of payment infrastructures. Lastly, average annual temperatures might influence the density of ATM networks as climate conditions affect the shoe-leather costs of accessing cash.

Data has been gathered from several sources including the Bank for International Settlements, the treasuries of central banks in Latin America, Portugal and Spain,[6] the International Monetary Fund and the World Bank. The information covers the period from 1991 to 2014 for 54 developing and developed economies, resulting in an

[5]Calderón and Liu (2003) find no evidence of significant causality from economic growth to M2 to GDP ratios.

[6]We thank the treasuries of the central banks that authorized the use of the statistics on currency in circulation by denominations from the confidential reports on “Estadísticas del Efectivo en Latinoamérica”.

unbalanced panel dataset with a maximum of 517 observations. Also, other series like self-employment, homicide rates, and indexes for political stability and labor freedom are considered in numerous robustness checks and econometric exercises using instrumental variables.

The final specifications are chosen after a careful analysis of the trade-offs of including additional variables and the loss in sample size that results, as many variables are only available for the last decade or so. We also refrain from presenting results for subsamples. This is due to the fact that the sample size for subgroups such as the OCDE countries and emerging economies, for example, reduce the sample size, making the estimation procedures unstable as we have to control for the "jumps". In addition, it is well documented in the literature that as the number of individuals in a panel N decreases relative to the number of time periods considered for each individual T statistical consistency is impaired (Baltagi (2014)).

Descriptive statistics for the pooled data can be found in Table 2. From these results, all main variables exhibit right biased distributions with significant levels of dispersion, which shows the heterogeneity that exists between the countries in our sample, due in part to the strong differences in population and GDP levels. By contrast, instruments seem to be more symmetric and tight in terms of standard deviations.

Variable	Mean	Median	Std. Dev.	Min	Max
Currency (†)	112,027	27,997	235,669	758	1,258,739
Large value currency (†)	70,136	18,169	165,658	136	1,209,312
Small value currency (†)	13,620	1,355	30,793	39	195,628
GDP (†)	1,173,195	336,000	2,270,982	7,752	14,700,000
Interest rate R (%)	5.46	3.85	6.62	0.02	74.68
ATM (‡)	49.56	39.80	37.70	0.28	185.65
EFTPOS (‡)	941.85	674.74	842.63	0.03	3,595.82
Unemployment	8.63	7.20	5.31	1.70	33.80
Telephone land lines (‡)	40.19	40.30	16.41	6.86	74.76
GDP growth (%)	3.12	3.03	3.10	-7.74	15.00
Temperature (Celsius degrees)	11.09	9.77	7.74	-7.01	28.27

(†) Values in millions of 2011 purchasing power parity dollars.

(‡) Values per 100,000 people.

Source: Authors' calculations.

Table 2: Summary statistics

Figure 2 shows that EFTPOS networks have grown steadily for most countries in the period 1991-2014. The mean annual growth rate for sampled countries is 31.2%, with 30.0% for OECD nations and 34.6% for the non-OECD counterparts. The countries with highest numbers are Estonia (95.1%), Czech Republic (81.3%) and Austria (76.3%), while the lowest annual average growth rates correspond to Norway (3.3%) and Finland (4.8%), with mature digital payment systems, and Turkey (5.6%).

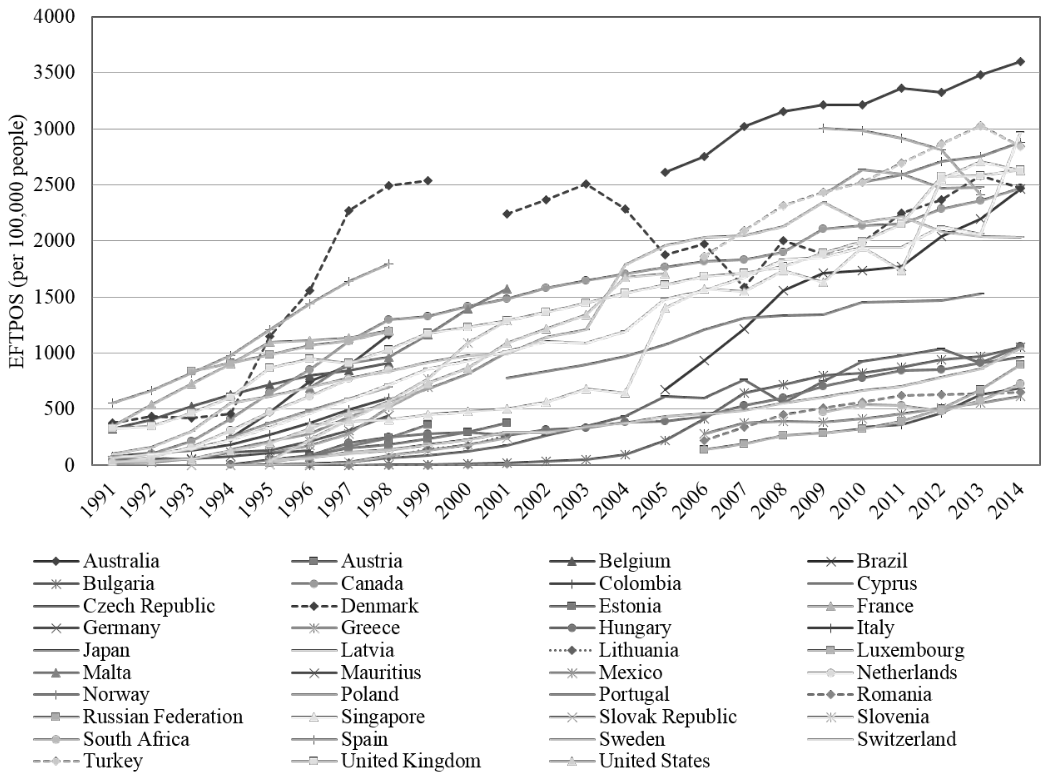


Figure 2: Evolution of EFTPOS

Figure 3 shows the relation between cash and EFTPOS for the years 1991, 1999, 2009 and 2014. From the cross section analysis, countries with higher EFTPOS rates show lower levels of currency in circulation over GDP for all of the considered time periods. This is especially true in the years 1999 and 2014, where exponential trends explain more than 20% of the variation in the data. Nevertheless, when considering the time series dimension histories vary, with countries where there is no evidence of a reduction in cash levels despite the strong growth in digital payments infrastructure such as Canada; other countries like Japan, Switzerland, the United Kingdom and the United States that show sustained increase in cash holdings to GDP, with annual growth rates around 3.6%, 1.7%, 1.1% and 3.4% respectively; while countries like Sweden exhibit a mean annual growth rate of -4.2% in currency over GDP.[7]

[7]Sweden, with the highest levels of EFTPOS densities in the sample, decreased its currency in circulation from 2009 to 2014. This happened even as it faced a reduction in its EFTPOS network, presumably favoring digital payments other than those made through cards (for example, mobile payments).

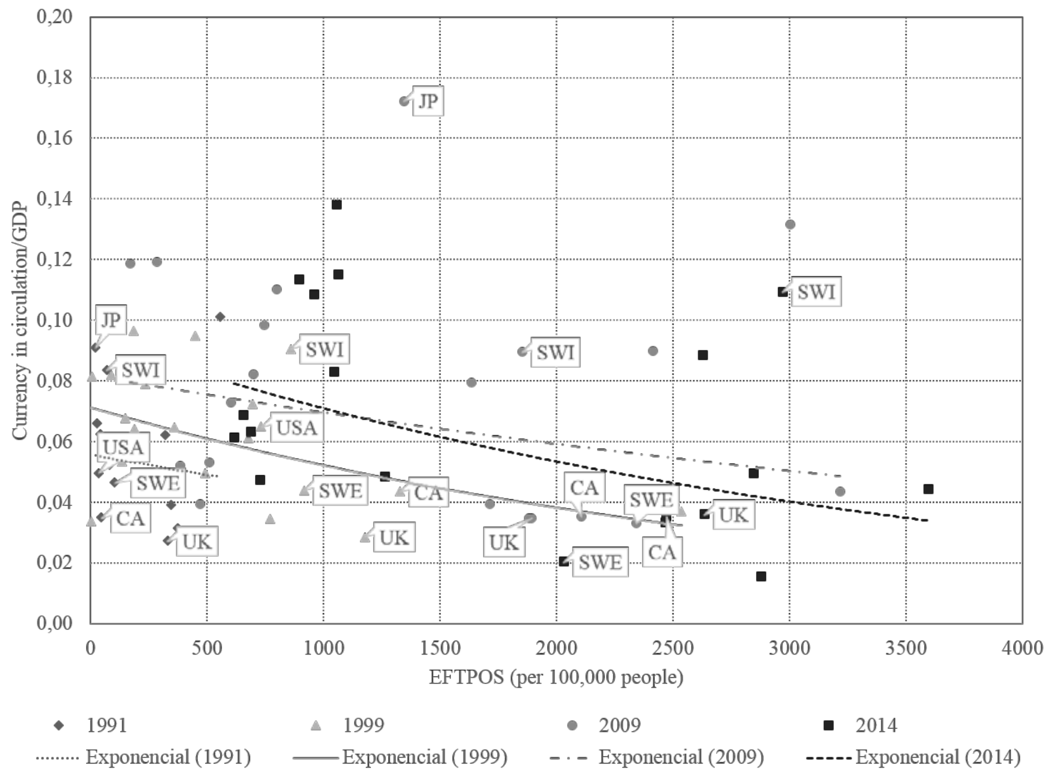


Figure 3: Currency vs. EFTPOS relation

The differential behavior observed in the currency-EFTPOS relationship when considering the cross-section and time series dimensions of the data, imply the need to use panel data techniques to account simultaneously for both dimensions. These techniques allow us to get consistent estimates of the relationships established in equations 1, 2 and 3 but making sure that they are not driven by third unobserved factors such country fixed effects. In this regard, Haussman tests for all of the proposed specifications show no evidence to reject the null hypothesis of random effects. We conjecture that this is the case because of the dummies used to control the "jumps", which work as proxies of individual fixed effects and, therefore, the models including them will likely show no need to further control for fixed effects, by, for instance, using within procedures.

Estimation is performed through the use of Generalized Method of Moments (Hansen (1982)) to enable the inclusion of instrumental variables and the use of weights and variance-covariance matrices that account for heteroscedasticity and auto-correlations among observations within each country's time series.

3 Results

Results obtained from the estimation of cash demand equations 1, 2 and 3, including their variations according to how the $EFTPOS$ variable is included, are presented in Table 3. Starting with equation 1 and the linear $EFTPOS$ specification, the total demand for currency depends positively on GDP with an income elasticity close to unity, consistent with the quantitative-theory base approaches (Knell and Stix (2006)), and negatively on short-term interest rates around a positive linear trend.[8] Regarding the $EFTPOS$ indicator, the effect is negative and statistically significant as expected from money demand theories that consider payment innovations (Alvarez and Lippi (2009); Alvarez and Lippi (2017)). When $EFTPOS$ is modeled as a quadratic relationship, most findings remain and ATM becomes statistically significant at the 10% level, with a positive effect on currency demand. To analyze the impact of $EFTPOS$ over currency demand for this case, the marginal effect $\gamma_1 + 2\gamma_2 EFTPOS$ is tested against zero, obtaining a significant negative and decreasing marginal effect. The third specification incorporates linear splines of $EFTPOS$, identifying a significant marginal negative effect at the third quartile range of the variable.[9]

The estimation outcomes for equation 2 (columns five to seven in Table 3) show the same relations for large denominations as those obtained for the model of total currency, but with higher levels of statistical significance specially for the ATM variable. The fact that bigger ATM networks encourage the demand for total currency, and large value denominations in particular, shows that lower costs of accepting cash prevail over the potential reductions in cash holdings due to more frequent trips to withdraw money. Furthermore, the income elasticity is now well below one, favoring money demand inventory theories and suggesting some economies of scale in the use of large value currency (Knell and Stix (2006)). Also, the magnitude of the effect of IR is less intense, showing that an increase of one hundred basis points in the short-term interest rates reduces large value currency demand by 1.4 basis points. Marginal effects for $EFTPOS$ in the quadratic and splines models are significant,[10] confirming the negative relation between electronic payments penetration and large value currency demand.

Finally, columns eight to ten in Table 3 show the estimation results for the small value currency demand (equation 3). First, the income elasticity remains positive and significant but greater than one. Interest rates hold their statistically relevant negative sign but with marginal effects higher than those found in the large value currency models. Also, ATM is now negative (and significant but only at the 10% significance level), suggesting that larger ATM networks increase the frequency of trips to withdraw small value denominations, reducing average cash holdings. Unemployment on the other hand becomes positive and significant, indicating that the possible associated increase in informality may rise the demand for cash, specially in the world of medium to low transaction values where small value denominations are used in exchange. In this case the effects of $EFTPOS$ over money demand are non-significant for all three model specifications.

The results seem to confirm the hypothesis that, for the period considered, digital payment innovations have had a significant effect on the demand for large value de-

[8]This coefficient is capturing the increasing money demand observed worldwide all else equal.

[9]Here, although γ_1 and γ_3 are not individually significant, the marginal effect $\gamma_1 + \gamma_3$ is.

[10]Hyptohesis $\gamma_1 + \gamma_3 = 0$ and $\gamma_1 + \gamma_3 + \gamma_4 = 0$ are strongly rejected.

nominations associated with high transaction values where payment instruments such as cards are shown to be safer and more convenient than cash (Arango-Arango et al. (2015a); Arango-Arango et al. (2015b)). They also dismiss the role that electronic payments have on the demand for small value denominations, mostly used on low value purchases where cash still dominates (Arango-Arango et al. (2018); Bagnall et al. (2016)). Yet, the strong negative effect of payment innovations on the demand for large value currency makes the overall effect of $EFTPOS$ on total currency also negative and significant.

As can be seen from the first line of the bottom panel in Table 3, the Haussman specification tests do not reject the hypothesis that the random effects model is the most efficient unbiased estimator. This is indeed the case in 8 out of the 9 specifications. In the case of the model for total currency demand the null hypothesis of the Haussman test is rejected at 5% confidence levels. We try estimating this model using the fixed-effects within estimator but parameter estimates are unstable and deviate from those found in models presented in columns three and four. Therefore, we decided to accept the null hypothesis of random effects using the more strict criteria of 1% [11]

[11]Note that the constant term in all estimations is negative and large showing that, taking antilogarithms, the demand for real currency balances tends to zero as factors such as income (GDP) decline substantially.

	log(Currency)			log(Large value currency denominations)			log(Small value currency denominations)		
	Linear	Squared	Spline	Linear	Squared	Spline	Linear	Squared	Spline
log(GDP)	1.0129***	1.0011***	0.9994***	0.9146***	0.8688***	0.8696***	1.1109***	1.1174***	1.1028***
Short-term R	-0.0875**	-0.0868**	-0.0862**	-0.0148***	-0.0142**	-0.0143**	-0.0510***	-0.0515***	-0.0497***
ATM	0.0065	0.0097*	0.0097*	0.0138**	0.0214***	0.0217***	-0.0126*	-0.0137*	-0.0114
Unemployment	0.0144	0.0150	0.0147	-0.0094	-0.0066	-0.0069	0.0187***	0.0185***	0.0173***
Linear trend	0.0584***	0.0570***	0.0544***	0.0389***	0.0431***	0.0438***	0.0011	0.0009	0.0010
EFTPOS	-0.0003***	-0.0007**	-0.0005	-0.0008***	-0.0016***	-0.0015***	0.0003	0.0004	-0.0005
EFTPOS squared		1.06E-7			2.05E-7***			-2.64E-8	
EFTPOS quartile 2									0.0009
EFTPOS quartile 3			-0.0002			0.0003			-0.0002
EFTPOS quartile 4			0.0006**			0.0006			
Constant	-120.2539***	-117.0710**	-111.9457***	-78.5761***	-85.7240***	-87.0067***	-9.5748	-9.3083	-8.9575
Haussman (†)	12.77**	10.48	12.04	11.17	9.09	10.36	15.85	13.82	12.62
$\gamma_1 + 2\gamma_2 EFTPOS = 0$ (‡)		5.76**			20.89***			1.56	
$\gamma_1 + \gamma_2 = 0$ (‡)									1.42
$\gamma_1 + \gamma_2 + \gamma_3 = 0$ (‡)									1.52
$\gamma_1 + \gamma_3 = 0$ (‡)			15.87***			10.27***			
$\gamma_1 + \gamma_3 + \gamma_4 = 0$ (‡)			0.12			12.42***			

Note: ***, ** and * denote statistical significance at the 1%, 5% and 10% levels, respectivelly.

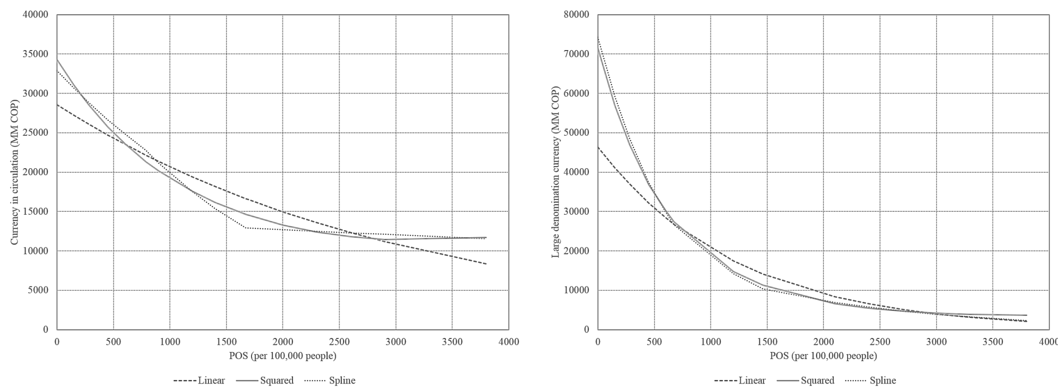
(†) H_0: the efficient model is consistent.

(‡) γ corresponds to γ in the currency model, γ^l in the large denomination model and γ^s in the small denomination model.

Table 3: Currency demand estimations

The differential relations between $EFTPOS$ and currency in circulation, when discriminating by denominational structure, are depicted in Figure 4, where the effect of $EFTPOS$ on total cash demand depends strongly on what happens with large value currency denominations.

Back of the envelop calculations of average variations in the explanatory variables for the period 2011-2014[12] show that the estimated impact of the average increase in the EFTPOS networks had a negative effect of 8.2% in the total demand for currency. This effect is almost equal to the combine positive effect on the demand for currency due to GDP growth (3.4%), ATM network expansion (3.0 %) and interest rates decline (1.43 %). If not for the positive trend in the demand for currency, driven by the demand for high denominations, the average demand for currency in the countries of our sample would have remained relatively constant during this period.



(a) Currency

(b) Large value currency denominations

Figure 4: Estimated relationship between money demand and $EFTPOS$

To facilitate the comparison with the results previously obtained by the empirical literature, Table 4 exhibits the findings for models on total currency in circulation, and large and small currency, where the dependent variable is the natural logarithm of the ratio of the previously mentioned monetary aggregates and GDP. With respect to total currency in circulation, columns two to four show that the short-term interest rate is statistically significant with a coefficient close to -0.09. The ATM variable turns out to be positive and significant together with the linear time trend. When analyzing $EFTPOS$, the results in Table 4 differ from those found in the previous literature as they are negative and significant, as can be seen directly from the inference tests on γ_1 in the linear $EFTPOS$ version or from the marginal effect tests of the quadratic and splines models.

For the large and small value currency models, the interest rate coefficients remain negative but significant only for the large value currency model, as in Amromin and

[12] The period for which we have homogeneous data for all countries on each of the samples used for the estimations in Table 3.

Chakravorti (2009) when they exclude the international currency countries from their estimations. Note, however, that the estimates of the restricted models in Table 4 differ considerably from those in Table 3, specially for large and small value currency models. This may indicate that restricting the modeling of currency demand to ratios of currency aggregates to GDP may bring some bias to the estimates of parameters such as interest rate elasticities. Other meaningful variables in Table 4 are ATM and the linear trend, for the large value currency case, and $UNEMP$ when referring to small value currency, similar to the findings in the previous literature. Amromin and Chakravorti (2009), for example, find evidence that variables that proxy for informality such as self-employment have a positive impact on the demand for large and small value currency for the OCDE countries. Finally, $EFTPOS$ significantly reduces the demand for total currency and large value denominations for the linear, quadratic and splines specifications, but has no effect on small value currency.[13]

[13]The constant term in these specifications remains negative and large, indicating that taking antilogarithms, the ratio of currency demand to GDP tends to zero as regressors are set to zero.

	log(Currency/GDP)			log(Large value denomination currency/GDP)			log(Small value denomination currency/GDP)		
	Linear	Squared	Spline	Linear	Squared	Spline	Linear	Squared	Spline
Short-term R	-0.0873**	-0.0870**	-0.0866**	-0.0212***	-0.0228***	-0.0237***	-0.0003	-0.0006	-0.0014
ATM	0.0067*	0.0096**	0.0095**	0.0092**	0.0135***	0.0132***	-0.0002	-0.0008	0.0010
Unemployment	0.0136	0.0150*	0.0148*	-0.0070	-0.0038	-0.0036	0.0133**	0.0122*	0.0131**
Linear trend	0.0579***	0.0569***	0.0543***	0.0335***	0.0365***	0.0363***	0.0032	0.0025	0.0013
EFTPOS	-0.0003***	-0.0007**	-0.0005	-0.0007***	-0.0013***	-0.0013***	-0.0001	0.0000	-0.0003
EFTPOS squared		1.04E-7			1.96E-7***			-5.24E-9	
EFTPOS quartile 3			-0.0002			0.0005			0.0002
EFTPOS quartile 4			0.0006**			0.0004			
Constant	-118.8184***	-116.7698***	-111.6476***	-69.8273***	-75.7542***	-75.4208***	-11.1956	-9.8497	-7.4684
Haussman (†)	12.04**	9.04	11.33	11.29	10.42	12.12	13.77	11.53	10.48
$\gamma_1 + 2\gamma_2 EFTPOS = 0$ (‡)		5.48**			22.30***			0.01	
$\gamma_1 + \gamma_3 = 0$ (‡)			16.50***			8.60***			0.11
$\gamma_1 + \gamma_3 + \gamma_4 = 0$ (‡)			0.12			9.89***			

Note: ***, ** and * denote statistical significance at the 1%, 5% and 10% levels, respectivelly.

(†) H_0: the efficient model is consistent.

(‡) γ corresponds to γ in the currency model, γ^l in the large denomination model and γ^s in the small denomination model.

Table 4: Currency demand estimations with unitary income elasticities

As a robustness check, we estimate all models in table 3, excluding the unemployment rate in each specification to see what impact collinearity may have on the elasticity of GDP on cash demand. We find no significant differences on elasticity estimates. In particular, the result of no unitary income elasticities still holds in the spline models for high and low denominations.[14]

4 Conclusions

The empirical literature that tries to identify the impact of digital payments on the demand for cash has come to contradicting conclusions. Bech et al. (2018) and Drehmann et al. (2002) argue that there is no evidence of digital payment innovations reducing the demand for currency. Bech et al. (2018) highlight the simultaneous growth in both the demand for cash and the digital payment networks in developed and developing economies. Yet, Amromin and Chakravorti (2009) find that the development of EFT-POS networks affects the demand for cash but only for small value banknotes.

To contribute to this debate we revisit the empirical modeling of currency demand both at the aggregate level and for large value and small value currency denominations. We construct a noble longitudinal dataset that covers the period from 1991 to 2014 for 54 developing and developed economies. Our results show that income and short term interest rates are important determinants of cash demand regardless of the specification, with the signs expected from theory and aligned with the previous empirical literature. Other variables like ATM networks and unemployment prove to be relevant, the former mainly on the demand for large value denominations and the latter on small value denominations.

The effect of digital payments on currency demand is studied through the development of the EFTPOS networks across countries and over time. A key finding is the significant inverse association of this variable with total currency in circulation and large value currency denominations, which contrasts with the results found in the previous literature. Our results are consistent with the recent literature showing that alternative digital payment instruments dominate cash only at purchases that are above the USD 15 to USD 20 range in developed economies.

Our results shows that, at the margin, the development of digital payment networks has significantly dented the demand for cash balances, almost counteracting the positive effects that economic growth, larger ATM networks and lower interest rates have had on the demand for cash across countries. They also imply that developing economies may see their demand for cash significantly tamed by the deepening of their digital payments infrastructures. Indeed, in some of these countries cash still accounts for the gross part of consumption both in transaction volumes and values, and even at USD 700 purchases cash accounts for more that 70% of consumer's payments (Arango-Arango et al. (2017)). Our results highlight the significant effects that relative transaction costs

[14]Estimations available upon request.

between cash and other means of payment may have in the transition of these economies to a less-cash society.

There is one additional effect related to the inclusion of linear time trends in our estimations, which results positive and statistically relevant for total currency in circulation and large value currency denominations. This trend, not explained by traditional factors modeling currency demand (the transactions motive), indicates that there are unobservable factors besides income, opportunity cost, payment innovations and labor market dynamics that have fostered the demand for cash across countries in the last two decades.These trends should be associated with the store-of-value function of cash: perhaps due to the use of cash as a saving vehicle (Stix (2013)), its demand as a free-risk asset, as seen in the great recession (Jobst and Stix (2017)), and as a way to hold wealth raised in the underground economy.

References

Alvarez, F. and Lippi, F. (2009). Financial innovation and the transactions demand for cash. *Econometrica*, 77(2):363–402.

Alvarez, F. and Lippi, F. (2017). Cash burns: An inventory model with a cash-credit choice. *Journal of Monetary Economics*, 90:99–112.

Amromin, G. and Chakravorti, S. (2009). Whither loose change? the diminishing demand for small-denomination currency. *Journal of Money, Credit and Banking*, 41(2-3):315–335.

Arango-Arango, C. A., Bouhdaoui, Y., Bounie, D., Eschelbach, M., and Hernandez, L. (2018). Cash remains top-of-wallet! international evidence from payment diaries. *Economic Modelling*, 69(C):38–48.

Arango-Arango, C. A., Hogg, D., and Lee, A. (2015a). Why is cash (still) so entrenched? insights from canadian shopping diaries. *Contemporary Economic Policy*, 33(1):141–158.

Arango-Arango, C. A., Huynh, K. P., and Sabetti, L. (2015b). Consumer payment choice: Merchant card acceptance versus pricing incentives. *Journal of Banking & Finance*, 55(C):130–141.

Arango-Arango, C. A., Solano, H. M. Z., and Ariza, N. F. S. (2017). *Ensayos sobre inclusión financiera en Colombia*, chapter Determinantes del acceso, uso y aceptación de pagos electrónicos en Colombia. Banco Interamericano de Desarrollo.

Attanasio, O. P., Guiso, L., and Jappelli, T. (2002). The demand for money, financial innovation, and the welfare cost of inflation: An analysis with household data. *Journal of Political Economy*, 110(2):317–351.

Bagnall, J., Bounie, D., Huynh, K. P., Kosse, A., Schmidt, T., and Schuh, S. (2016). Consumer cash usage: A cross-country comparison with payment diary survey data. *International Journal of Central Banking*, 12(4):1–61.

Baltagi, B. (2014). *Econometric Analysis of Panel Data*. Wiley.

Bech, M. L., Faruqui, U., Ougaard, F., and Picillo, C. (2018). Payments are a-changin' but cash still rules. *BIS Quarterly Review*, pages 67–80.

Buku, M. W. and Meredith, M. W. (2013). Safaricom and m-pesa in kenya: Financial inclusion and financial integrity. *Washington Journal of Law, Technology and Arts*, 8(3):375–400.

Calderón, C. and Liu, L. (2003). The direction of causality between financial development and economic growth. *Journal of Development Economics*, 72(1):321–334.

Cartas, J. and Harutyunyan, A. (2017). Monetary and financial statistics manual and compilation guide.

Chen, H., Felt, M.-H., and Huynh, K. P. (2017). Retail payment innovations and cash usage: accounting for attrition by using refreshment samples. *Journal of the Royal Statistical Society: Series A (Statistics in Society)*, 180(2):503–530.

Donovan, K. (2012). *Information and communications for development 2012 : maximizing mobile*, chapter Mobile Money for Financial Inclusion. World Bank.

Drehmann, M., Goodhart, C., Krueger, M., Boldrin, M., and Rose, A. (2002). The challenges facing currency usage: Will the traditional transaction medium be able to resist competition from the new technologies? *Economic Policy*, 17(34):195–227.

Eschelbach, M. and Schmidt, T. (2013). Precautionary motives in short-term cash management – evidence from german pos transactions. Working Paper 38, Deutsche Bundesbank.

Esselink, H. and Hernández, L. (2017). The use of cash by households in the euro area. Working Paper 201, European Central Bank.

Fujiki, H. and Tanaka, M. (2009). Demand for currency, new technology and the adoption of electronic money: Evidence using individual household data. Working Paper 2009-E-27, Institute for Monetary and Economic Studies, Bank of Japan.

Fung, B., Huynh, K., and Sabetti, L. (2014). The impact of retail payment innovations on cash usage. *Journal of Financial Market Infrastructures*, 3(1):3–31.

Hansen, L. P. (1982). Large sample properties of generalized method of moments estimators. *Econometrica*, 50(4):1029–1054.

Herwartz, H., Sardà, J., and Theilen, B. (2016). Money demand and the shadow economy: empirical evidence from oecd countries. *Empirical Economics*, 50(4):1627–1645.

Huynh, K., Schmidt-Dengler, P., and Stix, H. (2014). The role of card acceptance in the transaction demand for money. Working Paper 44, Bank of Canada.

Immordino, G. and Russo, F. F. (2017). Cashless payments and tax evasion. *European Journal of Political Economy*.

Jobst, C. and Stix, H. (2017). Doomed to Disappear? The Surprising Return of Cash Across Time and Across Countries. CEPR Discussion Papers 12327, C.E.P.R. Discussion Papers.

Knell, M. and Stix, H. (2006). Three decades of money demand studies: differences and similarities. *Applied Economics*, 38(7):805–818.

Lippi, F. and Secchi, A. (2009). Technological change and the households' demand for currency. *Journal of Monetary Economics*, 56(2):222 – 230.

Rogoff, K. (2016). *The Curse of Cash*. Princeton University Press.

Rogoff, K. S. (2014). Costs and benefits to phasing out paper currency. Working Paper 20126, National Bureau of Economic Research.

Stix, H. (2013). Why do people save in cash? Distrust, memories of banking crises, weak institutions and dollarization. *Journal of Banking & Finance*, 37(11):4087–4106.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