

# Cash Dollars Abroad\*

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## Abstract

This article examines the use of U.S. cash dollars as a secondary currency in informal transactions worldwide. While there is considerable interest in and a large theoretical literature on the use of secondary currencies, few empirical results have been established. The primary reason is that the amount of hard foreign cash in circulation in an economy is generally unknown. We provide a window into this underground world of cash transactions with the first systematic evidence on the demand for physical cash dollars across countries. We use an extraordinarily detailed new dataset with every wholesale shipment of physical cash dollars between 100 countries and the U.S. from 1990 to 2007. We define an extensive and intensive margin of currency substitution and examine the effects on each of a history of macroeconomic instability, competition with other currencies (the euro), and trade flows, along with the usual suspects such as country size, recent macroeconomic performance, and transaction costs. The highest inflation rate recorded over the previous 30 years significantly affects the demand for cash dollars, even after controlling for more recent movements in consumer price indexes. The intensive margin of dollar currency substitution has a positive relationship to the size of a country's trade flows and of its informal sector. Finally, we find a pattern of elasticities consistent with substitution from the dollar to the euro as a secondary currency in countries with significant trade with the euro area.

*Keywords:* Currency substitution; Secondary currency; U.S. dollar.

*JEL classification:* F24; F3; F31; F4; O17.

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## 1 Introduction

The first paper currencies – banknotes used as money – appeared in the seventh century in China, issued by local governments, and used as the primary circulating medium in their regions. Soon afterwards, the “secondary” use of other localities’ paper currencies became common.<sup>1</sup> Similar “secondary” use of foreign coinage became common soon after the advent of officially issued local coinage. For example, Kohn (1999) describes the use of secondary currencies in medieval Europe in the 12th century: “if the local coinage was particularly bad, as it was in Flanders, then better-quality foreign coins – sterlings for example – would be imported and would circulate alongside the domestic currency.” In this sense, secondary currencies have been around almost as long as have government-issued currencies, both banknotes and coins.

When it occurs on a large scale, the adoption and use of a secondary currency may have important implications for a country’s macroeconomic policy, both fiscal and monetary. Widespread currency substitution by a country’s residents can be a form of *de facto* dollarization, which in turn places constraints on domestic monetary authorities. A large amount of foreign currency circulating in a developing economy may make monetary policy interventions and exchange-rate stabilization programs less effective. It may also diminish the incentive for the government to finance deficits via domestic inflation, as a given amount of inflation will produce less seigniorage. Pervasive secondary currency use may also have important implications for central banks’ balance sheets, as the seigniorage earned from currency in circulation is a major source of their revenue.

While there has been considerable scholarly interest in and a large theoretical literature on the determinants of secondary currency use, there are very few established empirical results. The primary reason is that the amount of hard foreign cash in circulation is generally unknown. As Calvo and Végh (1992) note in their wide-ranging review of the literature, “At the empirical level, the study of currency substitution faces a fundamental problem: there is usually no data available on foreign currency circulating in an economy. Therefore the importance of currency substitution is basically unobservable.” Similarly, Feige et al (2002) describe the “fundamental problem of ‘unobservability’ that has plagued the currency substitution literature since its inception.” Secondary currencies’ “fundamental unobservability” follows from their generally

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<sup>1</sup>Goetzmann and Koll (2005).

tenuous (or ill-defined) legal status, and their use in informal (extra-legal or illegal) economic activity. For example, sales of €500 euro notes were recently banned in the United Kingdom due to their almost exclusive use there by the informal sector.<sup>2</sup>

This article provides a window into this underground world of cash transactions with the first systematic evidence on the determinants of the use of physical cash dollars across countries. We use an extraordinarily detailed dataset with every wholesale shipment of physical cash dollars between 100 countries and the U.S. from 1990 to 2007. Our data come from the Federal Reserve System’s international cash distribution operations.<sup>3</sup>

We develop and estimate a model of the determinants of the use of a secondary currency, which we define in our empirical analysis to be U.S. dollar banknotes. The adoption of a secondary currency by households and businesses depends on many factors, including country characteristics which determine its value relative to the domestic currency as a medium of transaction and store of value.<sup>4</sup> Our identification strategy is to use variation in country characteristics to proxy for the determinants of households’ and businesses’ use of dollars as a secondary currency. We separately identify the determinants of the extensive margin of secondary currency use, whether an economy as a whole adopts the use of dollars, from those of the intensive margin, the magnitude of any positive observed flows.

Our analysis yields several interesting findings. We find, first, an important role for the

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<sup>2</sup>In May 2010, currency exchange offices in the United Kingdom were banned from selling 500 euro banknotes because of their alleged use by money launderers. According to the BBC News, “The Serious Organised Crime Agency says 90% of the notes sold in the UK are in the hands of organised crime. Soca deputy director Ian Cruyton said 500 euros had become the currency of choice for gangs hiding their profits... There has been mounting international concern over the note, which is worth more than £400, and its use by criminals or tax evaders. Soca says that an eight-month analysis of movements of the note in the UK revealed that it was almost exclusively used by money launderers shifting cash for major crime gangs.” BBC News, “UK sales of 500 euro note halted,” [http://news.bbc.co.uk/1/hi/uk\\_news/8678886.stm?ad=1](http://news.bbc.co.uk/1/hi/uk_news/8678886.stm?ad=1).

<sup>3</sup>The Fed is responsible for facilitating the provision of U.S. dollar banknotes on demand, consistent with its responsibility to provide for an elastic supply of currency under the Federal Reserve Act. For each country we observe annual receipts of physical currency from the banknote operations departments of branches of depository institutions with accounts with the Fed from 1990 to 2007. An earlier, less extensive version of our dataset was used by Porter and Judson (1996).

<sup>4</sup>We emphasize that it is important to model the determinants of currency use separately from those of dollar deposits. Kamin and Ericsson (2003) find that the determinants of dollar deposits appear quite different from those of physical currency – underlining the importance of modelling the latter independently. As they note, “Dollar currency holdings have behaved very differently from dollar deposits in Argentine banks. The data on dollar deposits in domestic banks have formed the basis for almost all previous studies of currency substitution, since generally they are the only measures of currency substitution available. These data thus could be misleading indicators of dollarization.”

history of macroeconomic instability – the history of inflation over the previous generation is a key determinant of the use of cash dollars, even after controlling for more recent movements in prices. This finding can best be understood in the context of recent work on tail risk that emphasizes the importance of rare events that have, however, significant real consequences (Barro, 2006; Gabaix, 2008).

We also find evidence that competition between the dollar and other secondary currencies, notably the euro, has dampened the international use of cash dollars. This finding speaks to a broader issue, the fact that since the Second World War, the dollar has been the currency used most commonly in financial, trade, and cash transactions worldwide. Whether that will remain the case is the subject of an intensifying debate in global financial circles, where the euro is counted as the dollar’s dominant challenger.<sup>5</sup> Will the widespread secondary use of the dollar decline, and if so, how quickly? Will we witness a rapid coup (in currency time) over the next ten years by the euro, as some argue (Chinn and Frankel, 2008)? Or will we see a much more gradual process owing to the built-in inertia of the dollar’s prominent role (Eichengreen 2005)? We find that a country’s proportion of trade with the E.U., our proxy for access to the euro as an alternative secondary currency to the dollar, has a significant effect on both the extensive and intensive margin of currency substitution.

We also investigate the use of the dollar in international trade flows, finding that a higher share of trade relative to GDP is associated with greater secondary usage of dollar banknotes. Similarly, we find that countries with a large informal sector exhibit higher secondary usage of dollar banknotes. We also examine the effects of other variables from the secondary currency literature including recent macroeconomic performance and transaction costs. Our results thus complement and extend the existing empirical literature on secondary currencies, which is mainly comprised of country-level studies, and which we discuss in more detail in the next section.

Several key assumptions underlie our approach. First, we assume that higher flows of dollar banknotes from an individual country are associated with greater secondary use of dollar banknotes in that country. We believe this is a reasonable assumption for several reasons. First, almost all the variation in our banknote data is cross-sectional between countries (over 90 percent). Our interpretation of our empirical results implies that higher flows of banknotes

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<sup>5</sup>Goldberg (2010) reviews this literature.

from country A relative to country B to the U.S. reflects greater use of banknotes in country A. This implies that the stock of dollar banknotes does not vary dramatically over our sample period in any one country, and that the flows we observe reflect a nearly constant rate of redemptions of existing dollar banknotes in the country that are likely replaced through other channels. This assumption is consistent with the stylized fact that the overall stock of U.S. dollar banknotes abroad does not appear to have changed dramatically over the sample period. One can see this from the close movements of total payments and receipts flows to and from the world over the sample period illustrated in Figure 1. We do not have comparable data at the country level, due to the effects of non-reporting wholesalers on reporting of payments flows, as we discuss next.

Second, we model banknote flows assuming that there are two data-generating processes at work. The first process determines the extensive margin, whether an observed count (an annual banknote flow from a foreign country to the U.S.) is zero or non-zero, and then a second process determines the intensive margin, the size of any observed non-zero count. We model these two processes separately, for several reasons. First, we expect the determinants of the widespread adoption of dollars as a secondary currency differ, both in their nature and magnitude, from those driving fluctuations in dollar use on a year-to-year basis. Second, shipments from intermediaries generate “false” zeros for some developing countries in our data and may cause observed flows to understate the true flows across countries. One generally only observes the location of the first financial firm to receive U.S. dollar banknotes or the last to send them back to the U.S. A “false” zero is generated when a receipts shipment passes through a non-reporting intermediary – a wholesaler or bank – before reaching a reporting intermediary on its way to the U.S. Structural factors such as weak domestic financial institutions make some countries more likely to send or receive cash flows via intermediaries. Thus, there are countries that ostensibly use U.S. dollar banknotes to which and from which we observe no official flows. To the extent that we can identify the variables behind these structural differences, our model will correctly identify the determinants of this zero-generating process. After accounting for the zeroes in the data, our second model, a negative binomial regression model, should produce unbiased coefficients of the determinants of the intensive margin – of positive flows of U.S. currency.

We follow the literature on secondary currencies in focusing on the experience of devel-

oping economies. The need for a secondary currency does not drive the demand for dollar banknotes in most developed countries, which normally have low inflation rates and relatively stable economic conditions. Dollar banknotes in developed economies are thought to be used primarily for outbound tourism. When we do estimate our model for developed countries, we find that their banknote flows are not correlated with their macroeconomic performance.

Finally, we only estimate the determinants of receipts flows. We observe aggregate data on payments flows, but with incomplete reporting of their ultimate destination. Receipts flows have considerably better country coverage and reflect the final destination of dollar banknotes much more accurately than do the payments flows, which are dominated by shipments to wholesalers. To give an example of the differences between the two data sets, many developing countries in the sample report very few or no payments flows, but substantial receipts flows.

The paper is organized as follows: Section 2 discusses some key results from the literature, frames the main hypotheses that guide our analysis (the role of a history of macroeconomic stability, the informal sector, trade flows, and competition with the euro in the demand for cash dollars), and sets out a simple theoretical model to motivate the empirical analysis. Section 3 introduces and describes the cash-flow data. Section 4 describes our empirical model, and Section 5 presents our results. Section 6 concludes.

## **2 International Cash Flows**

### **2.1 What Do We Know?**

In this section, we describe several key results from the currency substitution literature and frame the main hypotheses to be tested in the empirical model. While there is a substantial theoretical literature on currency substitution, there are very few empirical papers that examine the determinants of a society's adoption of a secondary currency. Two prominent reviews of the literature are Calvo and Vegh (1992) and Giovannini and Turtelboom (1994).

The theoretical literature has primarily focused on search-theoretic models of money demand; a good overview is Craig and Waller (2000). These models examine the medium-of-exchange function of money, with no possibility for hoarding, which makes them less relevant for the case of currency substitution in developing countries. Most of the empirical currency substitution literature estimates the determinants of the flows or stocks of foreign-currency deposits (e.g. Agenor and Khan 1996), but omits foreign-currency-denominated banknotes

in circulation from the analysis because they are so difficult to measure. As we note in the Introduction, Kamin and Ericsson (2003) find that the determinants of dollar deposits appear quite different from those of physical currency, implying that it is important to model the latter independently. Such work has been substantially impeded by lack of data availability, particularly for developing countries. Several exceptions include Mongardini and Mueller (2000) who use data on secondary cash holdings to estimate currency-substitution ratios for the Kyrgyz Republic; Gruben and Lawler (1983) who examine the use of dollar banknotes and coins on the U.S. border with Mexico; Feige et al (2002) who use U.S. customs estimates of the stock of U.S. dollars in Latin America to analyze the drivers of dollarization in Argentina; and a very creative paper by Colacelli and Blackburn (2009) who use microeconomic data to estimate the determinants of secondary-currency adoption, also in Argentina.

A recent strand of the literature estimates the stock of banknotes held abroad (Porter and Judson 1996, Feige 1994, 1996, 1997, and Doyle 2001). Porter and Judson (1996) find that 70 percent of U.S. dollars were held abroad in the 1990s, rising from 40 percent in the 1960s.<sup>6</sup> Feige (1994, 1996, 1997) uses a factor analysis model to estimate that 35 percent of U.S. currency was held abroad in the mid-1990s, and has been rising over time. Doyle (2001) uses the regression coefficients from matched countries which reportedly have little or no currency abroad to estimate the domestic share of U.S., German, and Swiss currency, the remainder assumed to be held abroad. He finds that 40 percent of U.S. currency was held abroad in 1996, in contrast to 70-80 percent for Germany and Switzerland.

We build on this work by identifying the cross-country determinants of the use of U.S. dollar banknotes. We examine the following four hypotheses:

***Residents of countries with a history of macroeconomic instability use U.S. cash dollars as a store of value.*** The literature has generally found that the demand for a secondary currency is tied primarily (though not exclusively) to store-of-value uses in developing economies, and to medium-of-exchange uses in developed economies. Sprenkle (1993) argues that the use of physical currency varies across countries according to their level of development. He shows that the data on household currency holdings in the United States and other developed economies suggest that banknotes are used almost entirely as a medium

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<sup>6</sup>Our dataset is a substantially expanded and updated version of the dataset used by Porter and Judson (1996).

of exchange. The evidence from developing economies, in contrast, suggests that the use of foreign banknotes comes primarily from their store-of-value function due to concerns about the domestic currency's stability. The main motivation for adoption of a secondary currency is generally such a period of instability in the national currency. Such episodes are generally found in developing and transitional economies, and the main determinants are thought to be high domestic inflation (often caused by a monetizing of large fiscal deficits), a large exchange-rate depreciation, and low credibility of domestic monetary authorities.

A bout of high inflation or a large devaluation is thought to undermine confidence in a domestic currency for generations, though there is only survey evidence to confirm this hypothesis (see Stix, 2007). Calvo and Vegh (1992) note that the store-of-value function of money is the most vulnerable to domestic inflation, and so the first stage of currency substitution generally involves widespread hoarding of foreign banknotes, as foreign currency substitutes for domestic currency as a store of value. They document how the process of currency substitution then unfolds: "As high inflation continues, some prices – particularly of real estates, cars, and other 'big ticket' items – start to be quoted in foreign currency. . . . Not long after this, some transactions begin to be performed in foreign currency, especially those involving large transfers of funds. Domestic money, however, seems to retain its functions as unit of account and medium of exchange for almost all non-durable goods." As we discuss in the Introduction, we only include developing countries in our empirical work, as currency substitution does not drive demand for dollar banknotes in most developed countries, which normally have low inflation rates and relatively stable economic conditions. When we do estimate the model for developed countries, we find that currency flows appear unrelated to their macroeconomic performance.

*Countries with a large informal sector use U.S. cash dollars as both a means of transaction and a store of value.* It is generally believed that secondary currencies are commonly used as a medium of transaction in informal sector transactions in the U.S. and abroad (Feige 1994, 1996, 1997). As a prominent textbook in open-economy macroeconomics states, "It is an open secret among central bankers that a very large percentage of all currency is held by the underground economy" (Obstfeld and Rogoff, 1996, p. 515). Although the informal sector can use any physical currency, it requires a stable currency to retain value. The informal sector is generally defined as those economic activities that avoid the costs and



do not reap the benefits of formal legal institutions.<sup>7</sup>

*U.S. cash dollars are used in international trade, particularly in unreported transactions.* The dollar is commonly used as an invoice currency in international trade (Goldberg and Tille, 2008). Anecdotal evidence from the Federal Reserve’s cash operators indicates that a nontrivial number of trade transactions may be conducted in cash, particularly in countries with poor domestic banking systems or where firms have limited access to trade credit. As a result, one may expect countries with a larger share of trade relative to GDP to exhibit higher use of dollar banknotes. Cash dollars may be also be used for cross-border transactions that are not reported to customs or tax authorities, however, which could mean they have little relationship to official trade flows. One may *still* expect these transactions to be correlated with measures of trade barriers (particularly non-tariff barriers), given the well-established inverse relationship between trade barriers and trade flows. A significant negative relationship could provide some indirect evidence of the use of cash dollars in unreported trade flows. Our approach here is similar to that of the literature on tax evasion and other empirical studies attempting to uncover evidence of illegal or informal activity.<sup>8</sup> Though we cannot directly measure the size of unreported cross-border transactions, we may provide indirect evidence of their importance.

*Competition with the euro reduces the use of cash dollars as a secondary currency.* We also examine whether competition with the euro has dampened the use of cash dollars. This hypothesis speaks to an intensifying debate in global financial circles about whether the current, widespread secondary use of the dollar will decline, and if so, how

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<sup>7</sup>For example, Feige (1994) defines the informal economy as “those economic activities that circumvent the costs and are excluded from the benefits and rights incorporated in the laws and administrative rules covering property relationships, commercial licensing, labor contracts, torts, financial credit, and social security systems.”

<sup>8</sup>See, e.g., Feige (1979) who uses total dollar transactions relative to GDP to infer the size of the informal economy; Marion and Muehlegger (2008) who find evidence of tax evasion in the U.S. diesel fuel market by comparing the responsiveness of heating oil sales (a perfect untaxed substitute) to demand factors such as temperature before and after a decline in the costs of regulatory enforcement; Della Vigna and La Ferrara (2007) who use the response of weapons manufacturers’ equity prices to armed conflict events to identify evidence of illegal arms sales; and Hsieh and Moretti (2006) who provide evidence of corruption in Iraq’s oil for food program by comparing prices charged by Iraq for oil with those on the world market.

quickly.<sup>9</sup> With the introduction of the euro in 2002, residents of countries on the monetary union’s periphery reportedly began to use euros instead of dollars. In a study of household survey data from Croatia, Slovenia, and Slovakia, for example, Stix (2007) finds that far more households hold euros than dollars. Given the large volume of euros outstanding and their much larger denomination notes than those for the dollar (€500 notes versus \$100 notes), there is certainly scope for competition between the two currencies. Stix’s findings suggest that residents of countries with a high proportion of trade with the euro area should be more likely to substitute to euros than to dollars, given both their usefulness and availability, a hypothesis we test in our empirical model.

A European Central Bank study (2010) estimates that 20-25 percent of euro banknotes are held outside the euro zone (somewhat smaller than the share of U.S. dollars estimated abroad), most of which remains in the peripheral countries.<sup>10</sup> Substitution to the euro appears to be the strongest in south-eastern Europe, where survey data show that both Macedonia and Serbia have more than half of their total circulating currency in euros. This evidence also suggests that a country’s trade with the euro zone may be a good proxy for proximity to the euro zone, and thus for the extent of euro currency substitution, as we discuss further in Section 4.

## 2.2 Use of the Dollar as a Secondary Currency: Theoretical Framework

We develop a simple model of the demand for a secondary currency to motivate the empirical analysis. Consider a simple money-in-the-utility-function set-up for two countries, Home ( $H$ ) and Foreign ( $F$ ), drawing on Obstfeld and Rogoff (1996). The lifetime utility of the

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<sup>9</sup>Papaioannou and Portes (2008), in a survey of the international role of the euro, point to five determinants of a currency’s international status: the economic size, macroeconomic stability and growth, financial market depth, and political stability of the issuing country. In our sample period the euro zone was nearly the size of the U.S., with comparable rates of growth and inflation, suggesting that the euro could be a serious competitor for the dollar. The biggest barrier to euro adoption according to these measures is political risk arising from the nature of the eurozone being a collection of independent states, any of which could decide it would be more advantageous to have a domestic currency. Similarly, European Central Bank (2010) gives a summary of the current international use of the euro. They report that in international financial markets, there has been a significant increase in euro-denominated debt securities, but not in loans and deposits, since the advent of the euro. The share of euro assets in reserve holdings has increased, although this is largely due to appreciation of those assets against the U.S. dollar, and not to new purchases.

<sup>10</sup>Two-thirds of the outflows go to Switzerland and the United Kingdom, with most of the remainder going to Eastern Europe.

representative resident in the home country is

$$U_t = \sum_{s=t}^{\infty} \beta^{s-t} \left\{ u(C_s) + v \left[ \frac{M_{H,s}}{P_{H,s}} + g \left( \frac{\varepsilon_s M_{F,s}}{P_{H,s}} \right) \right] \right\} \quad (1)$$

Here  $M_H$  and  $M_F$  denote nominal holdings of domestic and foreign currency, respectively, and

$$g \left( \frac{\varepsilon_s M_{F,s}}{P_{H,s}} \right) = \alpha_0 \left( \frac{\varepsilon_s M_F}{P_{H,s}} \right) - \frac{\alpha_1}{2} \left( \frac{\varepsilon_s M_F}{P_{H,s}} \right)^2 \quad (2)$$

where  $1 - \beta < \alpha_0 < 1$ ,  $\alpha_1 > 0$  and  $\varepsilon_s = \frac{P_H}{P_F}$  is the domestic currency price of foreign currency. One can think of the  $g$  function as representing barriers to the local adoption of foreign currency resulting in a continuum of costs for its acquisition and use. From manipulating first-order conditions (for details of the derivation, see Appendix A), we get

$$\frac{M_{F,t}}{P_{F,t}} = \frac{1}{\alpha_1} (\alpha_0 - A) \quad \text{where } A = \frac{1 - \frac{\beta}{\pi_F^e}}{1 - \frac{\beta}{\pi_H^e}} \quad (3)$$

$$M_{F,t} = \frac{1}{\alpha_1} (\alpha_0 - A) P_{F,t} = \frac{1}{\alpha_1} (\alpha_0 - A) \frac{P_{H,t}}{\varepsilon_t} \quad (4)$$

where  $\pi_F^e$  and  $\pi_H^e$  are the expected foreign and home inflation rate, respectively. Taking logs gives

$$\ln M_{F,t} = -\ln \alpha_1 + \ln \left( \alpha_0 - \frac{1 - \frac{\beta}{\pi_F^e}}{1 - \frac{\beta}{\pi_H^e}} \right) + \ln P_{H,t} - \ln \varepsilon_t \quad (5)$$

Equation (5) forms the basis for our empirical specification. An increase in the costs to acquire and use foreign currency (a rise in  $\alpha_1$ ) leads to a decrease in the use of foreign currency. The use of foreign currency will be an increasing function of the expected inflation differential between the two countries  $\frac{\pi_H^e}{\pi_F^e}$ .<sup>11</sup> A rise in the domestic price level (a rise in  $P_H$ ) leads to an increase in the use of foreign currency while an appreciation of the home currency – a fall in  $\varepsilon$ , which corresponds to a rise in the domestic price level relative to the foreign price level, also leads to an increase in the use of foreign currency.

Several adjustments to the model are necessary to make it econometrically estimable. First,

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<sup>11</sup>When expected home inflation is less than or equal to expected foreign inflation, there will be no motivation to use foreign currency, as  $\alpha_0 < 1$ .

we drop U.S. inflation from the benchmark specification, as it does not differ across countries. Second, if one interprets Equation (5) as reflecting the per-capita demand for foreign currency, one needs a scale variable to reflect the different size of individual economies. We therefore add economic size to the variables to estimate the model across multiple countries. After these adjustments, Equation (5) becomes:

$$\ln M_{F,it} = -\gamma_1 \ln \alpha_{1,it} + \gamma_2 \ln \pi_{it}^e + \gamma_3 \ln P_{H,it} - \gamma_4 \ln \varepsilon_{it} + \gamma_5 \ln Y_{it} \quad (6)$$

where  $i$  denotes the origin country,  $t$  denotes year,  $\alpha_1$  are variables that increase the costs to acquire and use foreign currency in country  $i$  (discussed below),  $\pi_i^e$  is the expected inflation rate in country  $i$ ,  $P_{H,i}$  is the price level in country  $i$ ,  $\varepsilon_i$  is the bilateral nominal exchange rate between country  $i$  and the U.S, and  $Y_i$  is a measure of the economic size of country  $i$ .

### 3 Data Description

Our data, from the Federal Reserve System, consist of annual observations of official international wholesale shipments of U.S. dollar banknotes between 100 countries and the U.S. between 1990 to 2007.<sup>12</sup> Precisely, the sample consists of annual payments and receipts of physical currency to the banknote operations departments of branches of depository institutions with accounts with the Fed, by country of location. The overwhelming majority of these transactions use hundred-dollar denominations, and the shipment sizes are usually substantial. Most shipments are done by the pallet which typically contains 640,000 bills, or 64 million dollars. Summary statistics for the data are reported in Table 1.

As we note in the Introduction, these data have several limitations. The reported flows of dollar banknotes likely understate the true flows across countries, as many of the observed shipments go through non-reporting wholesalers who then send the money on to a final recipient who is often located in another country. One can see these limitations in the data by examining receipts and payments flows to and from the world and by region, as we do in Figure 1, which exhibits official monthly cash payments and receipts to and from the Federal Reserve System from 1990 to 2007. The figure illustrates that payments and receipts flows closely track one another for the world, but not for individual regions. Receipts are higher than

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<sup>12</sup>The countries in the sample are listed in Appendix C.

payments for most regions (exemplified here by flows to and from Asia and Latin America) except for those where wholesaler shipments dominate the data, notably Western Europe.

## 4 Empirical Model

As we discussed in the Introduction, we estimate the determinants of banknote flows assuming that there are two data-generating processes at work. The first determines the *extensive margin*, whether an observed count (an annual banknote flow to one country) is zero or non-zero, and then a second determines the *intensive margin*, the size of any observed non-zero count.

We expect our data to exhibit heteroskedasticity – as our dependent variable is non-negative, the conditional variance must approach zero as the conditional mean approaches zero. This is because large values of the conditional mean are unlikely to be observed near zero due to the fact that there cannot be any offsetting negative values. There is no such limit on larger values of the dependent variable, and we can therefore observe deviations in any direction, resulting in higher variance.

Silva and Tenreyro (2006) argue that the OLS estimator will be inconsistent for models with non-linear transformations in the presence of heteroskedasticity, without very specific assumptions on the form of the conditional variance. This is because the expected value of a random variable under non-linear transformation will depend upon higher-order moments of the distribution under these conditions. This violates the OLS assumption that the error term is uncorrelated with the regressors, which results in biased coefficients.

The solution suggested by Silva and Tenreyro (2006) is to use the Poisson pseudo-maximum likelihood estimator, since it will be consistent regardless of the form of heteroskedasticity as long as the conditional mean is correctly specified, and it is more efficient than other non-linear estimators because it weights all observations equally. Although the Poisson estimator is commonly used for count data, the authors point out that the formula is general, and can be applied to any non-negative data. The problem with the Poisson distribution is that it assumes equidispersion, where the mean and the variance are equal. In practice, most data exhibit overdispersion, where the variance is higher than the mean, as well as an abnormally large number of observations of zeroes.

Fortunately, there are extensions of the Poisson model that can account for these features

of the data. A similar distribution, which does not assume equidispersion, is the negative binomial distribution. The variance of the negative binomial distribution is equal to the mean plus a coefficient (commonly referred to as alpha) times the square of the mean – thus the Poisson model is nested within the negative binomial model, representing the special case where alpha is equal to zero. Given this feature, the negative binomial model is a superior alternative, since it can always assume the Poisson distribution if that best fits the data.

The case of excessive zeroes is somewhat more complicated. In some cases, the excessive zeroes are observed simply because of overdispersion, and the negative binomial model correctly accounts for these zeroes. However, our data still exhibits excessive zeroes even after taking into account the overdispersion, and thus we need a “zero-inflated” negative binomial model. The zero-inflated model, originally proposed by Lambert (1992) as an extension of the Poisson model, assumes that there are two processes at work. There is first a process that determines whether the observed count is zero or non-zero, and then a second process determines the size of the non-zero count.

We believe that this zero-inflated negative binomial model is the most appropriate model for the banknote data. A zero is generated in our data when the currency passes through non-reporting intermediaries from its destination of use back to the United States. There could be structural reasons why there are more such intermediaries for given countries, and insofar as we can identify variables that account for these structural differences, our model will correctly identify the zero-generating process. It is possible that the non-zero observations also contain a downward bias if this non-reporting process is only partial, where some flows are reported and others are not. By including these variables in the negative binomial model we control for this under-reporting as well. We should expect variables which increase the probability of a zero to be associated with lower flows, and vice versa. Ideally, we would prefer to have perfect data on all of the end-users of U.S. dollars, but given our constraints, this model efficiently accounts for the problems in our dataset and produces consistent estimates.

We are also concerned that the error terms within a given country may be correlated. The demand for U.S. dollars can be highly idiosyncratic for certain countries, such as Russia and Argentina, which would cause them to have consistently higher demand than typical macroeconomic variables would suggest (or vice versa). This would bias our standard errors downward in a simple pooled regression. To correct for arbitrary patterns of within-country

correlation, our standard errors are clustered at the country level.

The zero-inflated negative binomial model is a single model, but one composed of two separate components: a logit model to estimate the extensive margin, whether we observe a zero or non-zero observation, and a negative binomial regression to estimate the intensive margin, the expected size of a non-zero observation.<sup>13</sup> We estimate the following two models:

$$\begin{aligned} ZERO_{it} = & \gamma_0 + \gamma_1 \ln(Y_{it}) + \gamma_2 \ln(P_{it}) + \gamma_3 \ln(XR_{it}) + \gamma_4 \ln(D_i) + \\ & \gamma_5 \ln(30YRMAX_{it}) + \gamma_6 \ln(INFORMAL_i) + \gamma_7 \ln(OPEN_{it}) + \\ & \gamma_8 \ln(OPEN2_i) + \gamma_9 \ln(PROPEU_{it}) + \eta_{it} \end{aligned}$$

$$\begin{aligned} \ln(RECEIPTS_{it}) = & \beta_0 + \beta_1 \ln(Y_{it}) + \beta_2 \ln(P_{it}) + \beta_3 \ln(XR_{it}) + \beta_4 \ln(D_i) + \\ & \beta_5 \ln(30YRMAX_{it}) + \beta_6 \ln(INFORMAL_i) + \beta_7 \ln(OPEN_{it}) + \\ & \beta_8 \ln(OPEN2_i) + \beta_9 \ln(PROPEU_{it}) + \varepsilon_{it} \end{aligned}$$

where  $i$  denotes country and  $t$  denotes time. In the logit model, the dependent variable is equal to 1 if we observe zero receipts flows from country  $i$  in year  $t$  to the U.S. In the negative binomial regression, the dependent variable is defined as the log of total receipts of U.S. currency from country  $i$  in year  $t$ . The independent variables are defined as follows:

**$Y_{it}$ :** real GDP of country  $i$  at time  $t$ . GDP is an indicator of the total amount of economic activity, and all else equal a larger economy will require more currency for any given purpose.

**$P_{it}$ :** the consumer price index of country  $i$  at time  $t$ , indexed to 100 in the year 1994. One of the primary motivations for currency substitution, as noted in Section 2, is a significant risk of the government inflating away the value of the domestic currency. The price level in each year reflects the cumulative inflation experience of the country during our sample period, so we would expect a higher price level (that is, a history of recent inflation) to result in greater

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<sup>13</sup>For a more detailed description of the model, including the log-likelihood function, see Appendix B.

dollar use. To the extent that inflation expectations are backwards looking and draw on recent macroeconomic experience, we should expect the price index to capture their influence.

**XR<sub>it</sub>**: the nominal exchange rate index of the currency of country  $i$  for a single U.S. dollar at time  $t$ , indexed to 100 in the year 1994. An increase in our exchange rate is a depreciation of the domestic currency, which corresponds to a decline in the domestic price level relative to the foreign price level in our model, which in turn leads to a decline in the demand for foreign currency. Our exchange rate data come from the IMF's *International Financial Statistics* database.

**D<sub>i</sub>**: the distance between Washington D.C. and the capital city of country  $i$ . As in the gravity model literature this geographic distance measure proxies for a number of otherwise unobserved transaction costs, such as transportation and information costs, that serve as barriers to the interaction of economic agents, and so should lower the use of U.S. currency. Most of the distance data between Washington D.C. and other capital cities were provided by Jon Haveman,<sup>14</sup> and the missing values were calculated using Google's travel calculator.

**30YRMAX<sub>it</sub>**: the highest annual inflation rate over the past thirty years in country  $i$  at time  $t$ . Even when a bout of high inflation is subsequently brought under control, this can undermine the credibility of the domestic currency for those who lived through the event for decades, and so confidence may not be restored for a generation. This variable captures the hysteresis in inflation expectations, apart from the direct effect of recent inflation which is accounted for by the CPI. A history of high inflation should make a country's residents more likely to use a secondary currency.

**INFORMAL<sub>i</sub>**: a time-invariant measure of the size of the informal sector relative to GDP over the sample period in country  $i$ . A large informal sector should increase a country's use of dollar banknotes as both a medium of transaction and a store of value. This time-invariant measure identifies only cross-sectional variation in the receipts data. We expect that a country with a large informal sector that uses dollars should exhibit higher receipts in our data. Our measure of the size of the informal sector comes from the 2003-2004 observations

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<sup>14</sup> Available from <http://www.macalester.edu/research/economics/page/haveman/trade.resources/Data/Gravity/dist.txt>.



of Schneider (2004). Ideally we would like to observe the size of the informal sector over time, but cross-sectional measures with good country coverage are generally available only for one period. Schneider uses a “dynamic multiple-indicator, multiple-cause” model to estimate the size of the informal sector in 145 countries.<sup>15</sup>

**OPEN<sub>it</sub>**: the ratio of exports plus imports to GDP for country  $i$  at time  $t$ . If U.S. dollar banknotes are used for international trade transactions, a country that is more open to trade should exhibit higher use of U.S. dollar banknotes, because the transaction costs to acquire the currency should be lower than in a country without such trade. However, trade that occurs with physical currency may be unofficial, and so may not be counted in the official statistics. Our data on real GDP, CPI, and trade as a percentage of GDP come from the World Bank’s *World Development Indicators* database.

**OPEN2<sub>i</sub>**: the Heritage Foundation’s 2009 measure of trade freedom for country  $i$ . This index is a summary measure of each country’s total tariff and non-tariff barriers. Non-tariff barriers include quantity, price, regulatory, investment, and customs restrictions on trade, as well as direct government intervention in cross-border transactions through subsidies and other policies. This measure may capture the use of dollar banknotes in unofficial trade transactions better than would the official trade statistics that comprise  $OPEN_{it}$ . We hypothesize that lower trade barriers should be associated with higher levels of trade, both official and unofficial, and so greater use of dollar banknotes.

**PROPEU<sub>it</sub>**: the proportion of trade of country  $i$  at time  $t$  with the European Union, which proxies for the degree of competition between the dollar and the euro for use by domestic residents as a secondary currency. Residents of countries with a high proportion of trade with E.U. countries should have more euros available domestically, and so should be more likely to substitute to euros rather than dollars. Because the euro was only introduced as a physical currency in 2002, this variable takes the value of zero from 1990 to 2001. The data used to construct a country’s proportion of trade with the European Union come from the IMF’s

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<sup>15</sup>Schneider’s (2004) model estimates the size of the informal economy using a set of structural equations. The observed causes include variables such as tax burden and regulation, while the indicators include an increase in cash transactions and a decrease in labor market participation.

*Direction of Trade Statistics.*

$\eta_{it}$ : a stochastic error term with a standard logistic distribution.

$\varepsilon_{it}$ : a stochastic error term that is normally distributed.

We summarize the expected signs for each variable discussed here and for the coefficients in Equation (6) in Table 2. Recall that the  $\alpha_1$  term represents variables that increase the costs to acquire and use foreign currency in country  $i$ ,  $P_i$  is the price level in country  $i$ ,  $\pi_i^e$  is the expected inflation rate in country  $i$ ,  $\varepsilon$  is the bilateral nominal exchange rate between country  $i$  and the U.S., and  $Y_i$  is a measure of the size of country  $i$ .

Figure 2 illustrates the relationship across countries between the extensive margin – the share of *zero* dollar observations in the total observations for each country in our data – and several key variables from our model: economic size, trade barriers, distance, and the historical experience with high inflation. Each data point in the figure represents a country, with the independent variables expressed as the log of the average value for that country. The figure shows that larger countries are less likely to exhibit zero dollar flows: real GDP exhibits a strong negative correlation with the share of zero observations, as expected. The size of a country’s trade barriers is also negatively correlated with the likelihood of observing zero dollar flows. Countries situated geographically close to the U.S. face much lower transaction costs, so we observe very few zeroes in this group. Finally, countries with the highest historical inflation rates in the sample are vastly more likely exhibit positive shipments of U.S. dollars, as illustrated in the lower right panel.

Figure 3 depicts the relationship between a country’s size, trade barriers, distance from the U.S., and proportion of trade with the E.U., respectively, and the intensive margin of currency substitution – the log of its average *positive* flows of cash receipts. A country’s real GDP is positively correlated with its cash receipts: larger economies use more cash dollars. Countries with lower barriers to trade also exhibit higher receipts flows, which is consistent with the use of cash dollars in unrecorded trade transactions. Transaction costs also play an important role, with countries that are closer geographically to the U.S. exhibiting uniformly high levels of receipts. Finally, countries with a high proportion of trade with the E.U. exhibit lower dollar receipts, consistent with greater use of euros as a secondary currency.

We do not use country fixed effects in our empirical specification due to our prior that several time-invariant variables, including the distance, informal economy, and trade institutions variables, are key determinants of banknote flows. By construction, these variables will pick up some of the fixed effects. Moreover, the interesting variation in our panel is virtually all cross-sectional. To illustrate this point, we compute the percentage of variance in the receipts data due to country and year dummy variables. We find that over 90 percent of the variation in the receipts data is between countries.<sup>16</sup> Given these features of the data, most of our empirical work pools the data across countries. We emphasize, however, that all of our results from the pooled sample are robust to including time fixed effects.

Finally, we note that our model has some important similarities to the gravity model used heavily in the trade literature. The gravity model has been a standard workhorse for goods trade for decades. It states that the gross flow of trade between two countries should depend proportionally on their economic size and inversely on the distance between them. More recently it has been shown to explain cross-border financial flows fairly well, notably by Portes and Rey (2005) and di Giovanni (2005). We show that a model with key similarities to the gravity model (our use of a country’s economic size to account for “pull factors” in cross-border trade, and of distance to proxy for various transaction costs that may impede trade) explains variation in cross-border flows of banknotes reasonably well.

## 5 Results

This section presents our empirical findings. We first consider a baseline specification consistent with the simplest version of our theoretical model, as defined in Equation (6). We then introduce, individually and in combination, the other macroeconomic and institutional variables discussed in the previous section to test the effect of each on the secondary use of cash dollars.

In the negative binomial model all of the variables are in logs, so the coefficients can be interpreted as elasticities: the percentage change in dollar banknote receipts given a one-percent change in the independent variable. The results from the logit model are reported as marginal effects: The impact of a one-percent change in each independent variable on the

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<sup>16</sup>When we run the model with country fixed effects, only the real GDP variable retains its significance and only in the intensive margin model.

model’s estimated probability of observing a zero. We report the marginal-effects coefficient for each variable at its sample median, holding all other variables to their sample medians as well. In the logit model the dependent variable is equal to 1 if we observe a zero, so a positive coefficient indicates an increase in the probability of observing zero banknote flows, and vice versa. We therefore expect the opposite signs on each variable’s coefficients in the logit and the negative binomial models. Each specification also includes a constant term whose estimates are not reported, and all standard errors are clustered at the country level.

## 5.1 Baseline Specification

We consider first the effect of each country’s macroeconomic environment on its demand for dollars as a secondary currency. Our baseline specification from Equation (6) examines the effect of a country’s real GDP,  $Y_{it}$ , consumer price index,  $P_{H,it}$ , nominal exchange rate index with the U.S.,  $\varepsilon_{it}$ , and one transaction-cost variable,  $\alpha_{1,it}$ , our distance measure, on its use of cash dollars. As noted in Section 2, distance is a commonly used measure to proxy for a number of unobserved transaction costs in the gravity model literature, including information and physical transport costs. As we include these four variables in all our specifications as controls for the standard macroeconomic determinants of demand for a secondary currency, it is useful to see how well they perform before introducing the other variables of our model.

The results from this baseline specification are reported in the first column of Table 3. The results from the logit model – for the extensive margin – are in the top panel, and from the negative binomial model – for the intensive margin – in the bottom panel. As expected, an economy’s overall size is an important driver of both the extensive and intensive margin of currency substitution, though is most pronounced for the latter. A one-percent higher real GDP is associated with a 0.11 percent lower probability of observing zero dollar flows in any given year, and with 0.86 percent higher positive flows. Both coefficients are significant at the 1-percent level and appear remarkably stable across our other specifications. In our final specification which includes all the variables discussed in the previous section, the coefficient for the intensive margin model approaches a unit elasticity (as reported in column 7 of Table 3) which is an intuitively correct result for such a scale variable.

In contrast, a country’s cumulative inflation rate over the sample period, measured by the price level variable, has a significant effect both statistically and economically on the extensive

margin, but not on the intensive margin. A 1-percent higher price level is associated with a 0.31 percent lower probability of observing zero dollar flows in any given year. The price level does not figure significantly in the intensive margin in *any* of our specifications, however. This result is somewhat surprising, as one might reasonably expect recent movements in prices to affect the magnitude of secondary currency usage, after controlling for the initial adoption decision. We discuss this issue further below, in the context of the results from our generational memory variable.

The exchange rate index, which measures a currency's cumulative depreciation against the U.S. dollar over the sample period, does not significantly account for variation in either the extensive or intensive margin in any of our specifications. However, as cumulative depreciations are generally correlated with cumulative price inflation in our sample countries, we expect the effects of the exchange rate are already captured by the consumer-price-index variable.

Finally, distance, our proxy for unobserved transaction costs, plays an important role in both the extensive and intensive margins of currency substitution. A 1-percent greater distance between the U.S. and a foreign economy reduces the probability of observing zero dollar flows from that country by 0.17 percent in any given year, and implies roughly 1-percent lower observed flows on the intensive margin. Both estimates are stable and strongly significant across all remaining specifications, indicating (not surprisingly) that transaction costs play an important role in both the adoption and use of cash dollars as a secondary currency.

## 5.2 Generational Memory

We turn next to the four hypotheses laid out in Section 2.1. First, we consider the effects of what we call generational memory – the memory of a society that lasts for a generation, of the searing experience of the massive depletion of value of household and business savings via hyperinflation. As we discuss in Section 2, in most countries, the primary motivation for the adoption and continued use of a secondary currency is a period of instability in the national currency. Some authors have argued that a bout of high inflation undermines confidence in a domestic currency for a generation (Stix 2007). To test this hypothesis, we consider the effect of the maximum annual inflation rate recorded in each country over the previous 30 years. We use the survey evidence in Stix (2007) to motivate our use of this variable as a measure of

inflation expectations as well. To the extent that inflation expectations are backwards looking and draw on recent macroeconomic experience, the price index in our baseline specification should capture their influence. However, we also need to identify residents' perception of a "tail risk" that inflation will spiral out of control, for which the highest inflation rates recorded in the last generation is likely to be a good proxy.

The results from introducing this "generational memory" variable are reported in the second column of Table 3, and indicate that it is both economically and statistically significant for the extensive margin. Even after controlling for more recent movements in aggregate prices, we still find that a 1-percent higher historical inflation rate reduces the probability of observing zero dollar flows by 0.07 percent. This effect is strengthened once other variables are introduced to the regression: assuming the marginal rate stays constant, a doubling of the highest inflation rate experienced will result in a 10% decreased probability of observing a choice of zero dollar flows. Taken together with our findings for the CPI and real GDP, this result implies that the historical macroeconomic environment dominates the recent behavior of prices on the use of dollars, which strongly influences the decision whether to hold foreign currency at all on the extensive margin. While this variable also appears significant at the 5-percent level for the intensive margin, this is not robust to controlling for other variables, as shown in our final specification in column 7.

Our final specification implies that the usage of U.S. dollars is related not so much to average inflation but rather to the history of hyperinflation. This result is consistent with recent work on tail risk, which emphasizes the importance of rare events that have however significant real consequences, as we discussed in the Introduction.<sup>17</sup>

### 5.3 The Informal Economy

We turn next to the question of whether there is a relationship between the secondary use of cash dollars and the size of informal economic activity. As we discuss in Section 2, it is generally accepted that cash dollars are used in informal transactions worldwide, but there is little hard evidence of this. The informal economy literature suffers from many of the same unobservability problems as does the secondary currency literature, and we only have indirect methods of determining the amount of informal economic activity.

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<sup>17</sup>It also similar to the ratchet effect identified by Mongardini and Mueller (2000).

Despite these limitations, we are still able to identify a relationship between the informal sector and cash dollar use. As reported in column 3 of Table 3, our informal economy measure does not have a statistically significant effect on the extensive or intensive margin when introduced alone. However, once we control for the effects of the other variables we consider, it appears to have a substantial effect on the intensive margin. The results in column 7 indicate that a 1-percent higher level of informal activity is associated with a 1-percent higher level of banknote flows. Thus, a large informal economy does not make secondary currency adoption more likely in and of itself – after all, if the domestic currency retains its own value that will serve just as well – but conditional on widespread secondary currency adoption, there appears to be a near-unit-elastic increase in dollar use with each increment in informal economic activity. It is quite interesting that this elasticity appears almost identical to the elasticity of real GDP for the intensive margin.

#### **5.4 Trade Flows and Trade Freedom**

We examine next whether cash dollars facilitate international trade by introducing our first measure of openness, defined as a country’s total imports and exports divided by GDP, into the model. As reported in column 4 of Table 3, official trade flows appear to play an important role for the intensive, but not the extensive, margin of currency substitution: A 1-percent higher openness ratio is associated with 1.32 percent higher dollar flows. This effect weakens slightly when other variables are accounted for in column 7, but remains significant at the 1-percent level. Trade does not in itself encourage widespread secondary-currency adoption, but conditional on this, it does increase its scale considerably.

What about cross-border transactions that are not reported to customs or tax authorities? To address this question, we introduce our second measure of trade openness, the Heritage Foundation’s Trade Freedom Index, into the model. Although this variable appears to have no explanatory power for either the intensive or extensive margins when introduced alone, in the full model in column 7 its role in the intensive margin appears quite similar to that of officially reported trade flows. A 1-percent higher trade freedom index is associated with 3.6 percent higher banknote flows. As we discuss in Section 2, we draw on the well-established inverse relationship between trade barriers and trade flows to suggest that this result implies that unreported trade flows are likely associated with greater use of cash dollars. Our interpretation

of this coefficient draws on approaches used in the literature on tax evasion and in other empirical studies attempting to uncover evidence of illegal or informal activity. While we cannot measure directly the size of unreported cross-border transactions, we provide some indirect evidence of their possible importance.

## 5.5 Competition with the euro

Finally, we consider how a country's proportion of trade with the E.U. affects the use of dollars as a secondary currency. As per the discussion in Section 2, there has been heated debate about the global position of the dollar, and so the status of the euro as an alternative international currency has come into sharp relief. The euro appears to be making some headway in international financial markets, and there is strong evidence of euro cash holdings in the euro zone periphery countries, which we would expect to fill some of the need for secondary currency use and thus displace dollars in the same role. While we do not observe euro banknote flows to each of our countries, we can use the proportion of trade with the E.U. as a proxy for the availability of euros in a given country.

We find that this variable plays an important role in both the extensive and intensive margins of currency substitution. A 1-percent higher proportion of trade with the E.U. is associated with a 0.15 percent reduction in the extensive margin, as reported in the sixth column of Table 3, and this effect only strengthens in the final specification. For the intensive margin, a 1-percent higher proportion of trade with the E.U. is associated with 0.33 percent smaller intensive margin. Both the extensive and intensive margin results are significant at the 1-percent level, and in both specifications.

This is very strong evidence for competition between the dollar and the euro as alternative secondary currencies - not only do euros replace some of the total dollar stock in a country, but they also make it less likely for the country to demand dollar banknotes at all! Given the economic size and stability of the euro zone, there are clear transactional benefits for countries with close economic ties to adopt the euro, and so we see the euro continuing to displace the dollar in the euro-zone periphery. That said, euro-currency substitution has yet to extend beyond these immediate regional effects, whereas the dollar still remains the dominant secondary currency for the vast majority of the world's population.



## 6 Conclusion

While there is considerable interest in and a large theoretical literature on the use of secondary currencies, few empirical results have been established. The primary reason is that the amount of hard foreign cash in circulation in an economy is generally unknown. We provide a window into this underground world of cash transactions with the first systematic evidence on the demand for physical cash dollars across countries.

We introduce an extraordinarily detailed new dataset with every wholesale shipment of dollar bills between 100 countries and the U.S. over almost two decades, and examine the effects of a history of macroeconomic instability, competition with other currencies (the euro), and trade flows on both the intensive and extensive margins of currency substitution. We find an important role for the historical inflation experience: the highest inflation rate recorded over the previous 30 years significantly increases a country's probability of adopting dollars as a secondary currency, even after controlling for more recent movements in consumer price indexes. We also find a pattern of elasticities consistent with substitution from the dollar to the euro as a secondary currency in countries with significant trade with the euro area, both for the extensive and intensive margins of currency substitution. Finally, we observe that higher levels of trade and lower trade barriers are both important for the intensive margin of currency substitution. Our results parallel some of the findings regarding currency choice in international finance, and suggest that similar factors may be at work in the real economy. Given that currency substitution is usually an unobserved phenomenon, this paper represents an important first step in estimating the cross-country determinants of secondary currency adoption.

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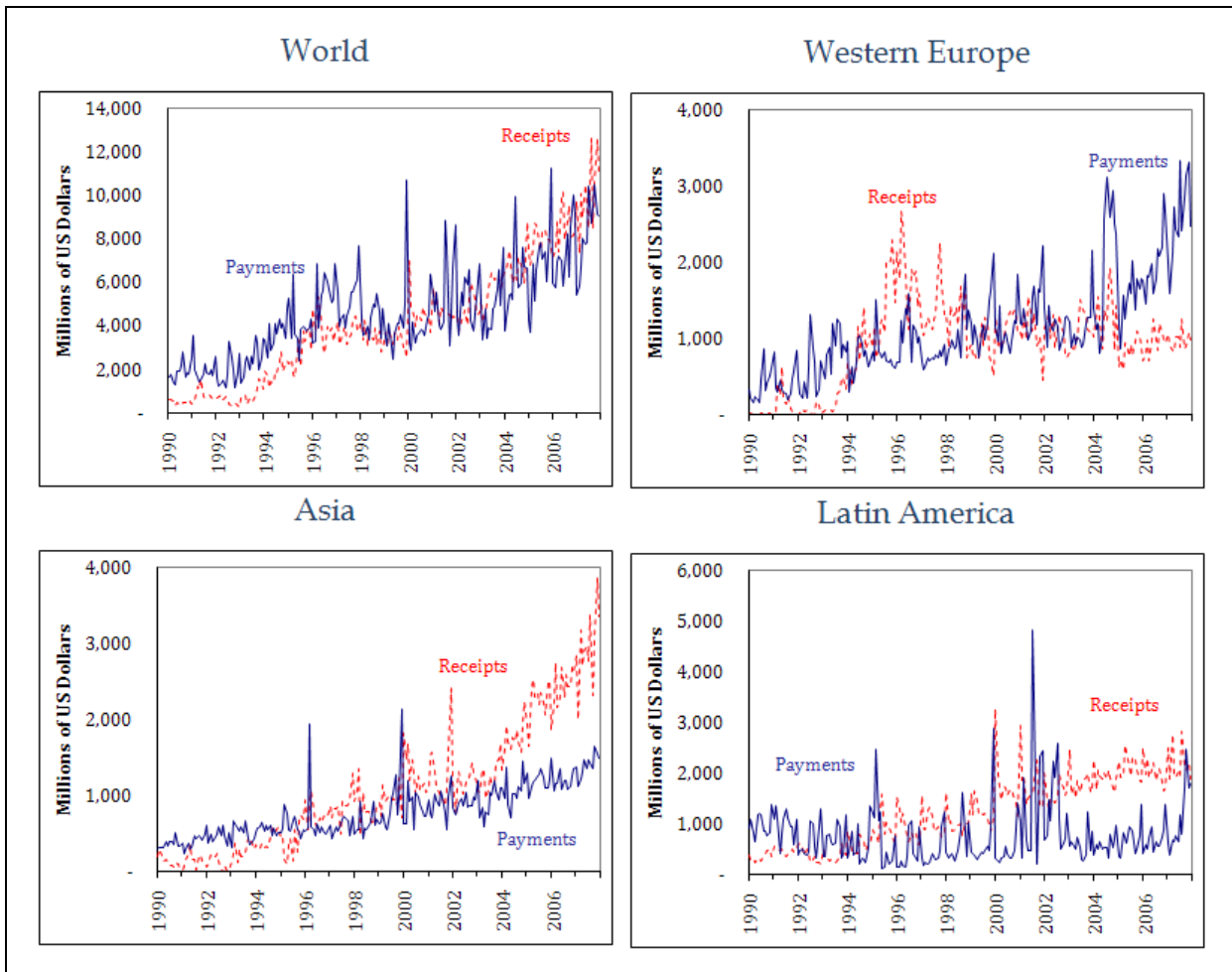


Figure 1: *Monthly Payments and Receipts of U.S. Dollar Banknotes, 1990-2007.* Source: *Federal Reserve System.*

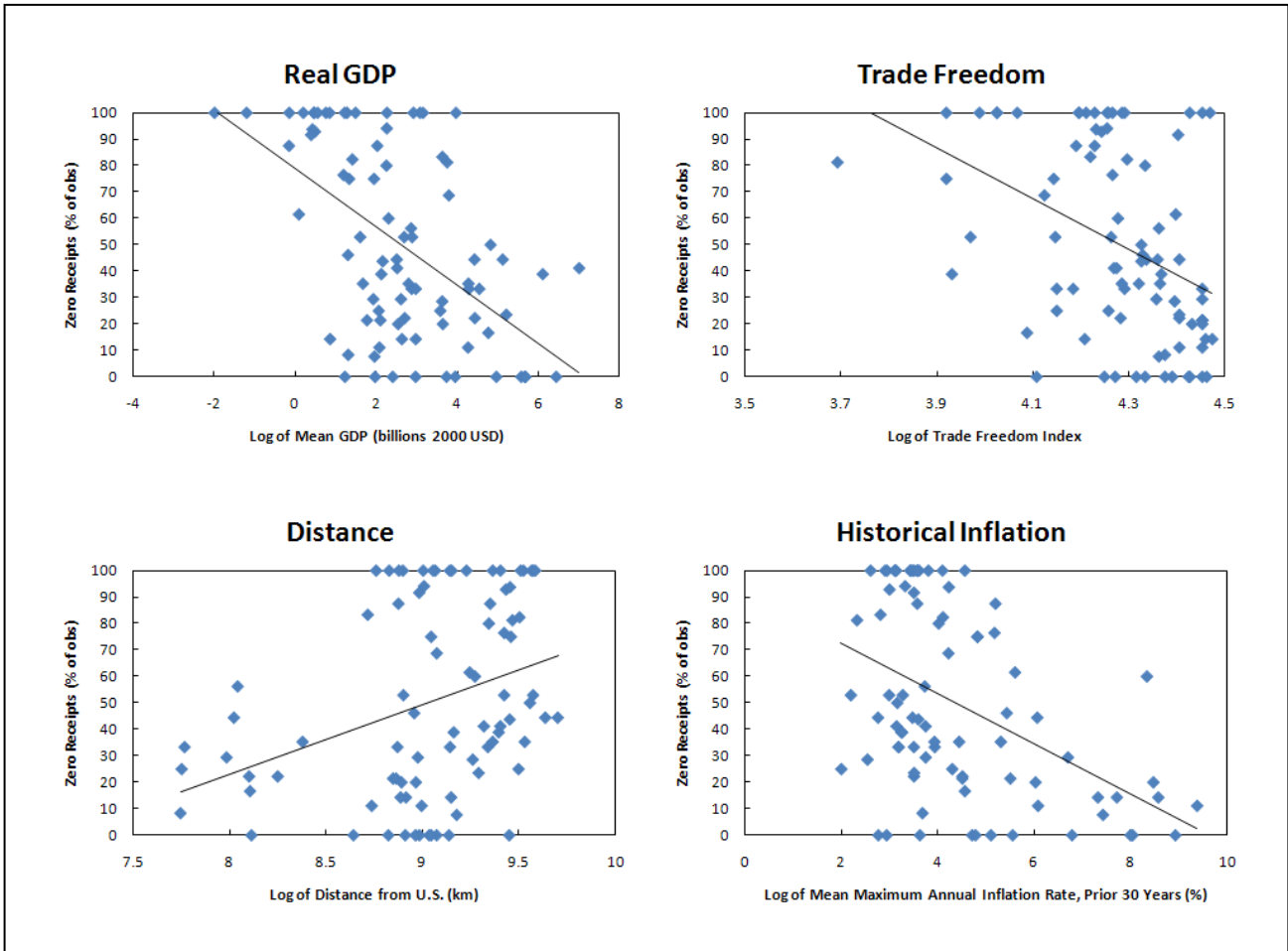


Figure 2: *Correlations of Selected Variables with Zero Dollar Receipts.* Gives the log average value of the variable plotted against the percentage of zero dollar observations in receipts. Each data point is a different country. Sources: *Federal Reserve System, World Bank, Heritage Foundation, Jon Haveman.*

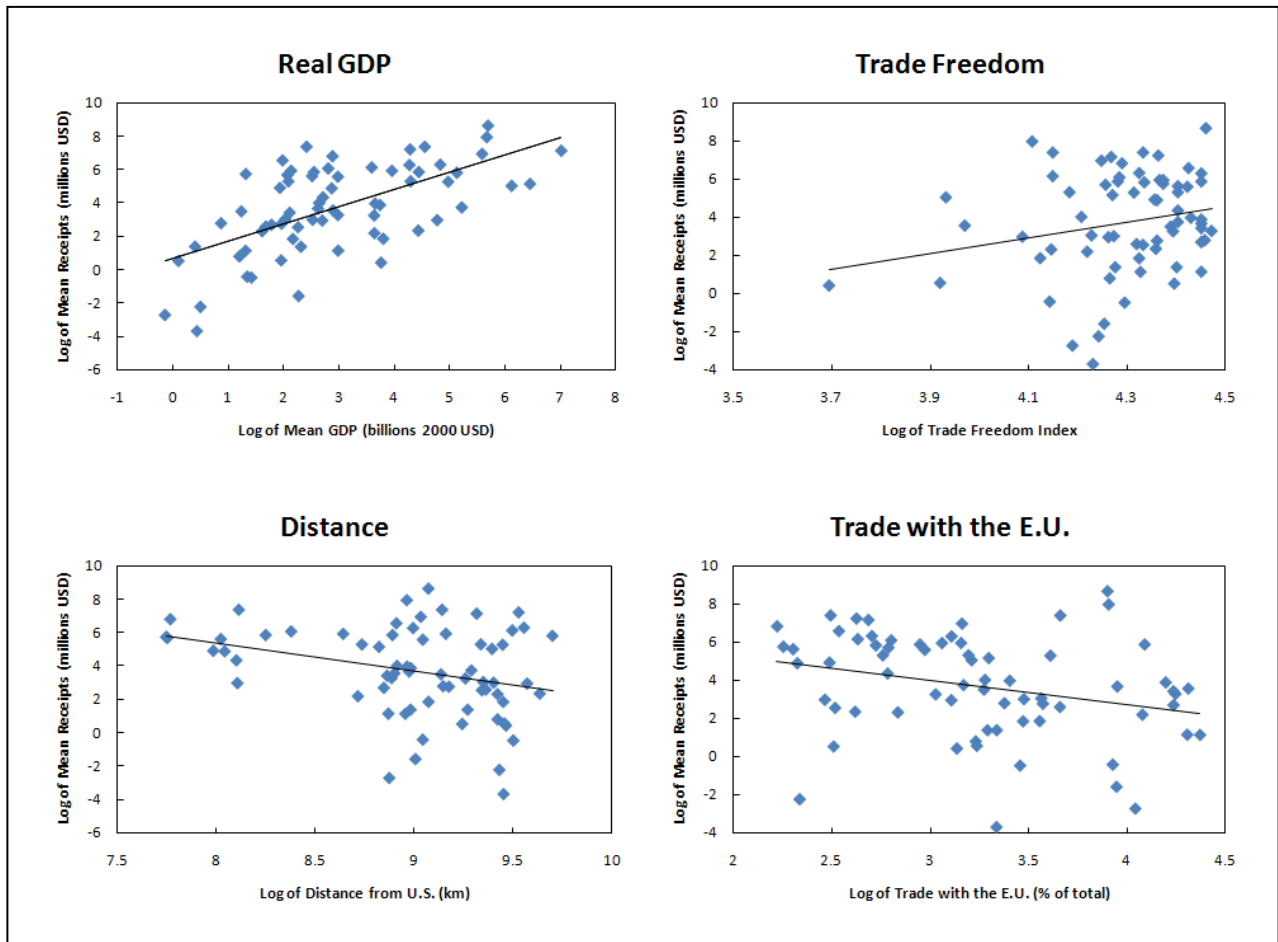


Figure 3: *Correlation of Selected Variables with Dollar Receipts.* Gives the log average value of the variable plotted against the log average size of dollar receipts. Each data point is a different country. Sources: *Federal Reserve System, World Bank, Heritage Foundation, Jon Haveman, International Monetary Fund.*



**Table 1: Summary Statistics**

Description	Mean	Standard Deviation	Min	Max
Receipts (millions USD)	258.3	993.9	0.0	19,686.7
Real GDP (billions constant 2000 USD)	59.6	161.9	0.1	2,113.0
Consumer Price Index (1994=100)	1,103.7	9,683.0	0.2	199,323.0
Nominal Exchange Rate Index (Foreign/USD, 1994=100)	7.6	84.6	0.0	2,824.4
Capital City Distance from Washington DC (km)	9,212.1	3,537.5	2,312.2	16,370.8
Highest Annual Inflation Previous 30 Years (%)	558.7	1,737.6	0.4	11,749.6
Size of the Informal Sector (% of official GDP)	41.0	11.6	15.6	68.3
Proportion of Trade to GDP (%)	73.4	35.9	10.8	228.9
Heritage Foundation Trade Freedom Measure	72.0	10.6	40.2	87.6
Proportion of Trade with the EU (%)	29.9	20.5	0.0	83.2

**Table 2. Empirical Variables, Hypothesized Effect on Receipts, and Corresponding Theoretical Variable**

Empirical Variable	Receipts	Zero Receipts	Theoretical Variable
Foreign Economy's Real GDP	+	-	$\Upsilon$
Consumer Price Index	+	-	$p$
Bilateral Nominal Exchange Rate (Units of Foreign Currency/USD)	+	-	$\varepsilon$
Distance	-	+	$a_1$
Highest Annual Inflation Rate Over Past 30 Years	+	-	$\pi^e$
Size of Informal Sector	+	-	$a_1, \Upsilon$
Openness to Trade	+	-	$a_1$
Heritage Index - Trade Freedom	+	-	$a_1$
Proportion of Trade with the European Union	-	+	$a_1$

**Table 3. Results**

Variable	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Foreign Economy's Real GDP	-0.11 [0.02]**	-0.09 [0.02]**	-0.12 [0.02]**	-0.11 [0.02]**	-0.10 [0.02]**	-0.11 [0.02]**	-0.13 [0.03]**
Consumer Price Index (1994=100)	-0.31 [0.11]**	-0.29 [0.11]**	-0.28 [0.11]*	-0.30 [0.11]**	-0.27 [0.10]**	-0.26 [0.10]**	-0.19 [0.11]
Nominal Exchange Rate Index (Foreign/USD, 1994=100)	-0.05 [0.18]	-0.07 [0.18]	-0.06 [0.20]	-0.08 [0.22]	-0.07 [0.17]	0.01 [0.14]	-0.08 [0.20]
Distance	0.17 [0.05]**	0.15 [0.06]**	0.17 [0.06]**	0.16 [0.05]**	0.16 [0.05]**	0.19 [0.05]**	0.13 [0.06]*
Maximum Annual Inflation (Previous 30 Years)		-0.07 [0.02]**					-0.10 [0.03]**
Size of Informal Sector			-0.14 [0.13]				-0.18 [0.13]
Openness to Trade				-0.09 [0.07]			-0.07 [0.07]
Heritage Index - Trade Freedom					-0.43 [0.25]		-0.31 [0.27]
Proportion of Trade with the EU						0.15 [0.04]**	0.19 [0.04]**
Foreign Economy's Real GDP	0.86 [0.18]**	0.89 [0.15]**	0.80 [0.20]**	1.07 [0.14]**	0.84 [0.16]**	0.85 [0.18]**	1.09 [0.12]**
Consumer Price Index (1994=100)	0.02 [0.25]	0.15 [0.22]	0.03 [0.26]	0.08 [0.18]	0.05 [0.25]	0.01 [0.23]	0.10 [0.18]
Nominal Exchange Rate Index (Foreign/USD, 1994=100)	-0.25 [0.30]	-0.33 [0.27]	-0.17 [0.33]	-0.29 [0.24]	-0.27 [0.27]	-0.26 [0.28]	-0.37 [0.20]
Distance	-0.96 [0.39]*	-1.02 [0.35]**	-1.06 [0.43]*	-1.16 [0.31]**	-0.80 [0.38]*	-0.92 [0.40]*	-0.96 [0.30]**
Maximum Annual Inflation (Previous 30 Years)		-0.19 [0.09]*					-0.15 [0.08]
Size of Informal Sector			0.30 [0.65]				1.03 [0.49]*
Openness to Trade				1.32 [0.28]**			0.83 [0.29]**
Heritage Index - Trade Freedom					2.94 [1.65]		3.55 [1.44]*
Proportion of Trade with the EU						-0.33 [0.12]**	-0.35 [0.08]**
Log Pseudolikelihood	-5913	-5867	-5388	-5655	-5859	-5841	-5077
Observations	1725	1694	1489	1675	1690	1703	1414

Notes: Clustered standard errors in brackets. Starred coefficients are significant at the \*5-, or \*\*1-percent level.

## A Use of the Dollar as a Secondary Currency: Theoretical Framework

In Section 2, we develop a simple model of the demand for a secondary currency to motivate the empirical analysis. This appendix contains the derivation of the estimating equation from the model's first-order conditions. Consider a simple money-in-the-utility-function set-up for two countries, Home ( $H$ ) and Foreign ( $F$ ), drawing on Obstfeld and Rogoff (1996, Chapter 8). The lifetime utility of the representative resident in the home country is

$$U_t = \sum_{s=t}^{\infty} \beta^{s-t} \left\{ u(C_s) + v \left[ \frac{M_{H,s}}{P_{H,s}} + g \left( \frac{\varepsilon_s M_{F,s}}{P_{H,s}} \right) \right] \right\} \quad (\text{A.1})$$

Here  $M_H$  and  $M_F$  denote nominal holdings of domestic and foreign currency, respectively, and

$$g \left( \frac{\varepsilon_s M_{F,s}}{P_{H,s}} \right) = \alpha_0 \left( \frac{\varepsilon_s M_F}{P_{H,s}} \right) - \frac{\alpha_1}{2} \left( \frac{\varepsilon_s M_F}{P_{H,s}} \right)^2 \quad (\text{A.2})$$

where  $1 - \beta < \alpha_0 < 1$ ,  $\alpha_1 > 0$  and  $\varepsilon_s = \frac{P_H}{P_F}$  is the domestic currency price of foreign currency. One can think of the  $g$  function as representing barriers to the local adoption of foreign currency resulting in a continuum of costs for its acquisition and use. Assume the Home government does not issue interest-bearing debt and does not hold interest-bearing assets. The resident's budget constraint is

$$B_{t+1} + \frac{M_{H,t}}{P_{H,t}} + \frac{\varepsilon_t M_{F,t}}{P_{H,t}} = (1+r)B_t + \frac{M_{H,t-1}}{P_{H,t}} + \frac{\varepsilon_t M_{F,t-1}}{P_{H,t}} + Y_t - C_t - T_t \quad (\text{A.3})$$

where  $T$  denotes lump-sum net taxes paid to the home government,  $r$  is the world rate of interest, and  $B$  refers to net private holdings of bonds issued by foreigners. The first-order conditions of utility maximization with respect to domestic and foreign nominal money holdings and foreign bond holdings are

$$u'(C_t) = u'(C_{t+1}) \quad (\text{A.4})$$

$$\frac{u'(C_t)}{P_{H,t}} = \frac{1}{P_{H,t}} v' \left[ \frac{M_{H,s}}{P_{H,s}} + g \left( \frac{M_{F,s}}{P_{F,s}} \right) \right] + \frac{\beta}{P_{H,t+1}} u'(C_{t+1}) \quad (\text{A.5})$$

$$\frac{u'(C_t)}{P_{F,t}} = \frac{1}{P_{F,t}} v' \left[ \frac{M_{H,s}}{P_{H,s}} + g \left( \frac{M_{F,s}}{P_{F,s}} \right) \right] g' \left( \frac{M_{F,s}}{P_{F,s}} \right) + \frac{\beta}{P_{F,t+1}} u'(C_{t+1}) \quad (\text{A.6})$$

Using Equation (A.4) to replace  $u'(C_{t+1})$  with  $u'(C_t)$ , multiplying both sides of Equation (A.5) by  $P_{H,t}$  and both sides of Equation (A.6) by  $P_{F,t}$ , one can combine Equations (A.5) and (A.6) to get:

$$g' \left( \frac{M_{F,s}}{P_{F,s}} \right) = \frac{1 - \frac{\beta}{\pi_F^e}}{1 - \frac{\beta}{\pi_H^e}} \quad (\text{A.7})$$

where  $\pi_F^e$ ,  $\pi_H^e$  are the expected foreign and home inflation rate, respectively. Given the quadratic functional form assumed for  $g(\cdot)$ , it follows that the demand for foreign currency is given by:

$$\frac{M_{F,t}}{P_{F,t}} = \frac{1}{\alpha_1}(\alpha_0 - A) \text{ where } A = \frac{1 - \frac{\beta}{\pi_F^e}}{1 - \frac{\beta}{\pi_H^e}} \quad (\text{A.8})$$

$$M_{F,t} = \frac{1}{\alpha_1}(\alpha_0 - A)P_{F,t} = \frac{1}{\alpha_1}(\alpha_0 - A)\frac{P_{H,t}}{\varepsilon} \quad (\text{A.9})$$

## B The Log Likelihood Function for the Zero-Inflated Negative Binomial Model

The log likelihood function for the zero-inflated negative binomial model is:

$$\begin{aligned} \ln L &= \sum_{j \in S} \ln [F(\mathbf{z}_j \gamma) + (1 - F(\mathbf{z}_j \gamma)) p_j^m] + \sum_{j \notin S} \left[ \begin{array}{l} \ln(1 - F(\mathbf{z}_j \gamma)) + \ln \Gamma(m + y_j) - \ln \Gamma(y_j + 1) - \\ \ln \Gamma(m) + m \ln p_j + y_j \ln(1 - p_j) \end{array} \right] \\ m &= \frac{1}{\alpha} \\ p_j &= \frac{1}{(1 + \alpha e^{\mathbf{x}_j \beta})} \end{aligned}$$

where  $S$  is the set of observations with zero observed flows,  $F$  is the logit link function,  $\mathbf{z}_j \gamma$  is the vector of variables and parameters in the zero-inflation process,  $\mathbf{x}_j \beta$  is the vector of variables and parameters in the main process, and  $\alpha$  is the overdispersion parameter (equal to 0 if the process is Poisson).

Intuitively, an observation of zero could be a false zero due to non-reporting intermediaries, or a true zero because the true demand for dollar banknotes is zero. The two terms inside the first summation sign account for each possibility respectively: maximizing the probability of observing a zero, plus estimating the negative binomial coefficients weighted by the probability of not observing a zero (that is, that zero is the true demand). For positive observed flows, the first term maximizes the probability of not observing a zero, while the remaining terms are identical to the negative binomial log likelihood function.

## C Countries in Sample

**Table C.1: List of Countries in Sample**

Albania	Gabon	Peru
Algeria	Georgia	Philippines
Antigua	Ghana	Romania
Argentina	Guatemala	Russia
Armenia	Guinea	Rwanda
Azerbaijan	Guyana	Saudi Arabia
Bahrain	Haiti	Senegal
Bangladesh	Hong Kong	Seychelles
Barbados	India	Sierra Leone
Belarus	Indonesia	Slovakia
Belize	Ivory Coast	Slovenia
Benin	Jamaica	Solomon Islands
Bhutan	Jordan	South Africa
Bolivia	Kenya	Sri Lanka
Botswana	Kuwait	Sudan
Brazil	Laos	Suriname
Bulgaria	Latvia	Swaziland
Cambodia	Lithuania	Syria
Cameroon	Madagascar	Tanzania
Central African Rep.	Malawi	Thailand
Chad	Malaysia	Togo
Chile	Mali	Tonga
China	Malta	Tunisia
Colombia	Mauritius	Turkey
Costa Rica	Moldova	Uganda
Croatia	Mongolia	Ukraine
Cyprus	Morocco	Uruguay
Dominica	Mozambique	Venezuela
Dominican Republic	Nepal	Zambia
Ecuador	Niger	Zimbabwe
Egypt	Nigeria	
El Salvador	Pakistan	
Estonia	Panama	
Ethiopia	Papua New Guinea	
Fiji	Paraguay	

## D Logit Model with Coefficients

**Table D.1. Results Reported as Coefficients**

Variable	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Foreign Economy's Real GDP	-0.55 [0.11]**	-0.49 [0.09]**	-0.64 [0.12]**	-0.57 [0.12]**	-0.50 [0.10]**	-0.56 [0.11]**	-0.65 [0.15]**
Consumer Price Index (1994=100)	-1.59 [0.56]**	-1.48 [0.54]**	-1.47 [0.58]*	-1.56 [0.57]**	-1.42 [0.54]**	-1.35 [0.52]**	-0.99 [0.55]
Nominal Exchange Rate Index (Foreign/USD, 1994=100)	-0.26 [0.94]	-0.37 [0.92]	-0.32 [1.02]	-0.40 [1.14]	-0.35 [0.88]	0.07 [0.74]	-0.43 [1.01]
Distance	0.88 [0.28]**	0.78 [0.29]**	0.89 [0.30]**	0.80 [0.26]**	0.81 [0.27]**	0.98 [0.28]**	0.68 [0.30]*
Maximum Annual Inflation (Previous 30 Years)		-0.36 [0.11]**					-0.51 [0.17]**
Size of Informal Sector			-0.74 [0.66]				-0.92 [0.68]
Openness to Trade				-0.46 [0.37]			-0.35 [0.38]
Heritage Index - Trade Freedom					-2.23 [1.31]		-1.62 [1.40]
Proportion of Trade with the EU						0.80 [0.18]**	1.00 [0.20]**
Foreign Economy's Real GDP	0.86 [0.18]**	0.89 [0.15]**	0.80 [0.20]**	1.07 [0.14]**	0.84 [0.16]**	0.85 [0.18]**	1.09 [0.12]**
Consumer Price Index (1994=100)	0.02 [0.25]	0.15 [0.22]	0.03 [0.26]	0.08 [0.18]	0.05 [0.25]	0.01 [0.23]	0.10 [0.18]
Nominal Exchange Rate Index (Foreign/USD, 1994=100)	-0.25 [0.30]	-0.33 [0.27]	-0.17 [0.33]	-0.29 [0.24]	-0.27 [0.27]	-0.26 [0.28]	-0.37 [0.20]
Distance	-0.96 [0.39]*	-1.02 [0.35]**	-1.06 [0.43]*	-1.16 [0.31]**	-0.80 [0.38]*	-0.92 [0.40]*	-0.96 [0.30]**
Maximum Annual Inflation (Previous 30 Years)		-0.19 [0.09]*					-0.15 [0.08]
Size of Informal Sector			0.30 [0.65]				1.03 [0.49]*
Openness to Trade				1.32 [0.28]**			0.83 [0.29]**
Heritage Index - Trade Freedom					2.94 [1.65]		3.55 [1.44]*
Proportion of Trade with the EU						-0.33 [0.12]**	-0.35 [0.08]**
Log Pseudolikelihood	-5913	-5867	-5388	-5655	-5859	-5841	-5077
Observations	1725	1694	1489	1675	1690	1703	1414

Notes: Clustered standard errors in brackets. Starred coefficients are significant at the \*5-, or \*\*1-percent level.