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Working Paper

The determinants of international flows of US currency

Staff Report, No. 400

Provided in Cooperation with:
Federal Reserve Bank of New York

Suggested Citation: Hellerstein, Rebecca; Ryan, William (2009) : The determinants of international flows of US currency, Staff Report, No. 400, Federal Reserve Bank of New York, New York, NY

This Version is available at:
https://hdl.handle.net/10419/60731

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The Determinants of International Flows of U.S. Currency

Rebecca Hellerstein
William Ryan

Staff Report no. 400
October 2009

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The Determinants of International Flows of U.S. Currency

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JEL classification: F24, F3, F31, F4, O17

Abstract

This paper examines the determinants of cross-border flows of U.S. dollar banknotes, using a new panel data set of bilateral flows between the United States and 103 countries from 1990 to 2007. We show that a gravity model explains international flows of currency as well as it explains international flows of goods and financial assets. We find important roles for market size and transaction costs, consistent with the traditional gravity framework, as well as roles for financial depth, the behavior of the nominal exchange rate, the size of the informal sector, the amount of remittance credits, the degree of competition with the euro, and the history of macroeconomic instability over the previous generation. We find no role for official trade flows of goods. Our results thus confirm several hypotheses about the determinants of using a secondary currency.

Key words: currency substitution, secondary currency, gravity model, U.S. dollar

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1. Introduction

While there is considerable interest in and a large theoretical literature on the determinants of the adoption of a secondary currency, there are very few established empirical results.[1] Similarly, despite the large share of U.S. dollar banknotes held abroad (estimated by Porter and Judson, 1996, to be greater than 70 percent), there are few established facts about the country-level determinants of their use. Such work has been impeded by limited data availability. We believe this paper provides the first systematic evidence of country-level determinants of international flows of U.S. currency.

Our empirical analysis focuses on testable predictions about various macroeconomic, financial, and institutional variables from the existing theoretical and empirical literature, paying special attention to such country attributes as the role of financial depth, the informal sector, and the history of macroeconomic stability. We identify which of the traditional functions of currency -- a medium of exchange that reduces transaction costs, a store of value, or a nominal unit of account -- are associated with the use of dollar banknotes in particular countries. We find that a gravity model characterizes the determinants of the size and direction of cross-border flows of currency across a large number of countries as well as it does cross-border flows in goods and financial assets.

We introduce a new panel data set of bilateral gross cross-border currency flows between the U.S. and 103 countries. The data come from the Federal Reserve System's international cash distribution operations and include all wholesale shipments of dollars to and from the U.S. abroad. 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

[1] As Calvo and Végh (1992) observe in their review of the literature, "In the final analysis, the relevance of currency substitution is an empirical issue…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," in their review of the literature: "The major limitation of any analysis of unofficial dollarization is that the amount of foreign currency in circulation (FCC) is typically unknown. Despite the substantive importance of the issues cited, earlier research has provided no reliable empirical information concerning the actual extent of unofficial dollarization."

from the banknote operations departments of branches of depository institutions with accounts with the Fed from 1990 to 2007.

The main contribution of this paper is to characterize the country attributes that determine households' and businesses' decisions to adopt the use of dollars as a secondary currency. Theoretical models addressing this issue generally focus on the medium-of-exchange function of money, however, with no possibility for hoarding, which excludes store-of-value considerations and so makes them less relevant for the adoption of secondary currency in developing economies, which is our focus (e.g. Kiyotaki and Wright, 1989). In practice, 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.

Our results both complement and extend the existing empirical literature on the adoption of a secondary currency. The literature, comprised mainly of country-level studies, has found the main determinants of adoption of a secondary currency to be domestic inflation, the behavior of the exchange rate, transaction costs, and the credibility of domestic monetary and fiscal authorities. We find important roles for market size and transaction costs, consistent with the traditional gravity framework, as well as for the recent and historical behavior of such macroeconomic aggregates as the inflation rate and the exchange rate, financial depth, the size of the informal sector, the size of remittance credits, and the degree of competition with the euro. We find no role for official goods trade flows.

Several key assumptions underlie our approach. First, we assume that higher flows of dollar banknotes from an individual country are associated with greater 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) with only a small fraction (about 1 percent) over time. Our interpretation of our empirical results implies that higher flows of banknotes 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, to account for limitations in our data, we model banknote flows assuming that there are two processes at work. The first process determines 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 size of any observed non-zero count. We believe that this is an accurate model given the large number of shipments from intermediaries in the data, which creates "false" zeros for many developing countries and causes 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 zero is generated when a receipts shipment passes through a non-reporting intermediary 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 zero-generating process. After accounting for the zeroes in the data, our second process, a negative binomial regression model, should produce unbiased coefficients for the determinants of positive flows of U.S. currency, allowing us to get identification off of our macroeconomic variables.

Third, we only include developing countries in our empirical work. The large number of wholesalers located in developed countries inflates the measured flows of cash to those countries whose ultimate destination is in fact other countries. In addition, the need for a secondary currency does not drive use of dollar banknotes in most developed countries, which normally have low inflation rates and relatively stable economic conditions. Observed flows of dollars to developed economies are thought to be used primarily for outbound

tourism. For these reasons, we find that banknote flows to developed countries are not correlated with their macroeconomic performance.

Fourth, we only estimate the determinants of receipts flows, not payments flows, although we observe data on the latter. The receipts flows have much greater country coverage in the data, and we believe they reflect the final destination of dollar banknotes much more accurately than do the payments flows, which appear dominated by shipments to wholesalers. As a result, 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 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 the empirical results on the country-level determinants of cross-border flows of U.S. dollar banknotes. Section 6 concludes.

2. International Currency Flows

2.1 What Do We Know?

This section describes several key results from the currency substitution and other relevant literatures to frame the main hypotheses to be tested in the empirical model. While there is a substantial theoretical literature on currency substitution, defined as the use of multiple currencies in a given country, there are very few papers empirically analyzing the determinants of adoption of a secondary currency. Two prominent reviews of the literature are Calvo and Vegh (1992) and Giovannini and Turtelboom (1992).

The theoretical literature has primarily focused on search-theoretic models of money demand; a good overview is Craig and Waller (2000). These models focus on 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 focuses on estimating the determinants of the flows or stocks of foreign-currency deposits (e.g. Agenor and Khan 1996) and omits foreign-currency-denominated banknotes in circulation from the analysis, because they are so difficult to measure. Such work has been substantially impeded by lack of data availability, particularly for developing countries. Several recent exceptions include Mongardini and Mueller (2000) who use data on secondary cash holdings to estimate currency-substitution ratios for the Kyrgyz Republic, 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 Colacelli and Blackburn (2005) 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. 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 he believes 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 determinants of the flows of U.S. dollar banknotes abroad. Some key results from the literature follow.

Countries with a history of high inflation or significant exchange-rate volatility use U.S. 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 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 can undermine confidence in a domestic currency for generations (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 recent domestic currency appreciation demand more U.S. dollars. When the price of dollar banknotes falls following a domestic currency appreciation, demand for them should rise, and vice versa. Evidence of this relationship has been found in several country-specific studies of currency substitution that use data on foreign cash in circulation (Mongardini and Mueller, 2000; Feige et al, 2002).

Countries with greater financial depth exhibit more use of U.S. dollars. Financial depth is generally defined as the size or liquidity of a country's financial markets relative to its overall economy activity (GDP). Two prominent surveys of the literature on financial depth are Caprio and Honohan (2001) and Demirguc-Kunt and Levine (2001). We draw on this literature to hypothesize that a country with a better developed banking system is more likely

to send and receive currency directly from the Federal Reserve. Any existing use of U.S. dollar banknotes is thus more likely to be recorded in a country with a greater financial depth.

Countries with significant international trade may use U.S. dollars as a medium of transaction and a store of value. 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 greater share of trade relative to GDP to exhibit higher use of U.S. dollar banknotes.

Countries with a large informal sector use U.S. dollars as a medium of transaction and a store of value. It is well known that secondary currencies are commonly used as a medium of transaction to engage in transactions in the informal sector 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 the formal institutions regarding property relationships, financial credit, and the like.[2]

Countries with high levels of trade with the EMU use fewer U.S. dollars. With the introduction of the euro in 2002, residents of countries on the EMU periphery have been found to substitute to euros instead of U.S. dollars suggesting some competition between the two currencies. In a study of household survey data from Croatia, Slovenia, and Slovakia, Stix (2007) finds that far more households hold euros than dollars. Given the large volumes of euros outstanding and their much larger denomination notes than those available for the dollar, there is certainly scope for competition between the two currencies. Stix's findings

[2] 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."

suggest that residents of countries with a high proportion of trade with the EU should be more likely to substitute to euros than to dollars, given both their usefulness and availability.

Countries with large incoming remittance payments have higher receipts of U.S. dollars. Remittances represent another channel through which countries can obtain foreign currency which makes them a substitute for official shipments. Remittance payments to developing countries were estimated to be $300 billion in 2006 (Orozco, 2007). Almost half of these payments go through informal channels and a large share occur through the "widespread practice of hand-carrying money when travelling" (Orozco, 2007, p. 11). Thus, higher inflows of dollar banknotes from remittances should increase observed receipts of dollar banknotes.

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

We draw on these stylized facts from the literature to 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 representative resident in the home country is

$$U_t = \sum_{s=t}^{\infty} \beta^{s-t} \left\{ u\left(C_s\right) + v\left[\frac{M_{H,s}}{P_{H,s}} + g\left(\frac{\varepsilon_s M_{F,s}}{P_{F,s}} \right) \right] \right\} \qquad \textbf{(0)}$$

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

$$g\left(\frac{\varepsilon_s M_F}{P_{F,s}} \right) = a_0 \left(\frac{\varepsilon_s M_F}{P_{F,s}} \right) - \frac{a_1}{2} \left(\frac{\varepsilon_s M_F}{P_{F,s}} \right)^2 \qquad \textbf{(0)}$$

where $1-\beta < a_0 < 1, a_1 > 0$ 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

$$\frac{M_{F,t}}{P_{F,t}} = \frac{1}{a_1}\left(a_0 - A\right) \text{ where } A = \frac{1-\frac{\beta}{\pi_F^e}}{1-\frac{\beta}{\pi_H^e}} \qquad \textbf{(0)}$$

$$M_{F,t} = \frac{1}{a_1}\left(a_0 - A_t\right)P_{F,t} = \frac{1}{a_1}\left(a_0 - A_t\right)\frac{P_{H,t}}{\varepsilon} \qquad \textbf{(0)}$$

where π_F^e, π_H^e are the expected foreign and home inflation rate, respectively. Taking logs gives

$$\ln M_F = -\ln a_1 + \ln\left(a_0 - \frac{1-\frac{\beta}{\pi_F^e}}{1-\frac{\beta}{\pi_H^e}}\right) + \ln P_F - \ln \varepsilon \qquad \textbf{(0)}$$

Equation (5) forms the basis for our empirical specification. An increase in the costs to acquire and use foreign currency (a rise in a_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 $\frac{\pi_H^e}{\pi_F^e}$.[3] A short-term depreciation of the home currency (a rise in ε) also leads to a decrease in the use of foreign currency.

Several adjustments to the model are necessary to make it econometrically estimable. First, we drop U.S. inflation from the benchmark specification, as it does not differ across countries. Second, we add economic size to the variables to estimate the model across multiple countries. After these adjustments, equation (5) becomes:

$$\ln M_{F,it} = -\gamma_1 \ln a_{1,it} + \gamma_2 \ln \pi_{it}^e - \gamma_3 \ln \varepsilon_{it} + \gamma_4 \ln S_{it} \qquad \textbf{(0)}$$

where *i* denotes the origin country, *t* denotes year, a_1 are variables that increase the costs to acquire and use foreign currency in country *i* (discussed below), π_{it}^e is the expected inflation

[3] When expected home inflation is less than or equal to expected foreign inflation, there will be no motivation to use foreign currency, as $a_0 < 1$.

rate in country i, ε is the bilateral nominal exchange rate between country i and the U.S, and S_i is a measure of the economic size of country i.

3. **Data Description**

Our data consist of a panel comprised of 103 countries with annual observations from 1990 to 2007. The data are compiled from several sources. The proprietary data of official international wholesale shipments of U.S. dollar banknotes come from the Federal Reserve Systems. The data consist 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. Most of these transactions use hundred-dollar denominations, and the shipments are usually substantial. Most shipments are done by the pallet which typically contains 640,000 bills, or 64 million dollars.

Our data on real GDP, GDP per capita, inflation, and trade as a percentage of GDP come from the World Bank's *World Development Indicators* database. Nominal exchange rates and private credit as a percentage of GDP come from the International Monetary Fund's *International Financial Statistics* database. Private credit is defined as the sum of bank and non-bank financial institutions' claims on the private sector.[4] The data used to construct a country's proportion of trade with the European Union come from the International Monetary Fund's *Direction of Trade Statistics*. The remittance data come from the International Monetary Fund's *Balance of Payments and International Investment Position Statistics*.

The data on de-facto pegs to the U.S. dollar were graciously provided by Jay Shambaugh.[5] Shambaugh uses observed exchange-rate fluctuations to determine whether a country is pegged to the dollar, regardless of their official stated policy.

Most of the distance data between Washington D.C. and other capital cities were provided by Jon Haveman,[6] and the missing values were calculated using Google's travel calculator. A

[4] These are IFS codes 22d and 42d, respectively.
[5] The data through 2004 are publically available at http://www.dartmouth.edu/~jshambau/. Shambaugh provided us with data through 2006, so we used the final value for our 2007 observations.
[6] Available from http://www.macalester.edu/research/economics/page/haveman/trade.resources/Data/Gravity/dist.txt.

country's distance from the equator is measured as the absolute value of the latitude of the capital city from the equator and comes from Dollar and Kraay (2004).

Our time-invariant measure of the size of the informal sector comes from the 2003-2004 observations of Schneider (2004). Ideally we would like to observe the size of the informal sector over time, but large cross-sectional measures are available only for very short time-series, which would severely limit the number of observations in our panel. Schneider uses a "dynamic multiple-indicator, multiple-cause" model to estimate the size of the informal sector in 145 countries.[7]

As we noted in the introduction, the data have several limitations. The observed 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 shows official monthly cash payments and receipts to and from the Federal Reserve System from 1990 to 2007. The figure illustrates that payments and receipts flow closely track one another for the world, but not for individual regions. Receipts are higher than 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**

To account for these limitations in our data, we empirically estimate banknote flows assuming that there are two processes at work. The first process determines whether an observed count (an annual banknote flow to one country) is zero or non-zero, and then a second process determines the size of any observed non-zero count.

We have strong theoretical reasons to think that our data exhibit heteroskedasticity. Since our dependent variable is non-negative, the conditional variance must approach zero as the

[7] The model estimates the unknown coefficients using a set of structural equations, which specify the relationships between the variables. 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.

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 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.[8] 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-inflation 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 might be 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. After accounting for the excess zeroes, our second model will provide unbiased coefficients, allowing us to get identification off of our macroeconomic variables. 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.

Finally, note that we do not use country fixed effects in our empirical specification because we have a strong prior that several time-invariant variables, including the distance and informal economy variables, should be a major determinant 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. The

[8] Note that there are other possible methods of correcting for excessive zeroes, such as zero-truncated or "hurdle" models, but we believe that the process we are observing is well-characterized by zero-inflation.

variation in the receipts data between countries accounts for 92.4 percent of its total variation. Controlling for the variation between countries, the variation in receipts due to the time effects is 1.1 percent. Given these features of the data, most of our estimation pools the time-series and cross-section data.

4.1 A Model of Zero Gross Flows of U.S. Currency

Our zero-generating process is a logistic regression, to predict whether we observe a zero or non-zero cash flow for each country in each year:

$$ZERO_{it} = \gamma_0 + \gamma_1 \ln(GDP_{it}) + \gamma_2 \ln(30YRMAX_{it}) + \gamma_3 \ln(PROPEU_{it}) + \gamma_4 \ln(CRED_{it}) + \eta_{it}$$

where *i* denotes countries and *t* denotes time. The dependent variable is equal to 1 if we observe zero receipts flows from country *i* in year *t* to the U.S. The independent variables are defined as follows:

GDP_{it}: the real GDP of country *i* at time *t*. Real GDP is a measure of economic size. A larger country is likely to demand more dollar banknotes, all else equal, which should reduce the probability of observing zero receipts.

$30YRMAX_{it}$: the highest annual inflation rate over the past thirty years in country *i* at time *t*. 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. Countries with a history of significant past inflation are thus more likely to engage in currency substitution, reducing the probability of observing zero receipts.

$PROPEU_{it}$: the proportion of trade with the European Union for country *i* at time *t*. Countries with a high proportion of trade with E.U. countries should be more likely to substitute to euros rather than dollars, thus increasing the probability of observing zero receipts.

$CRED_{it}$: the ratio of private credit to GDP for country *i* at time *t*. The ratio of private credit-to-GDP is a measure of financial depth and economic development. A country with a better

developed banking system is more likely to send and receive currency directly, hence lowering the probability of observing a zero.

η_{it} : a stochastic error term with a standard logistic distribution.

Figure 2 illustrates these relationships for the receipts data. It maps the average relationship across countries between the log of the country-specific mean of each of the independent variables in the zeros model and the log of the percentage of zero dollar observations in each country's total obsevations. Each data point in the figure is a different country.

We summarize the expected signs for each variable discussed here and for the coefficients in Equation (6) in Table 2. Recall that a_1 are variables that increase the costs to acquire and use foreign currency in country *i*, π_i^e is the expected inflation rate in country *i*, ε is the bilateral nominal exchange rate between country *i* and the U.S, and S_i is a measure of the economic size of country *i*.

4.2 A Model of Positive Gross Flows of U.S. Currency

Next, we estimate the determinants of positive observed cash flows with a *gravity model*, a simple empirical model originating in the trade literature.[9] The gravity model has been a standard workhorse for goods trade for decades and more recently it has been applied successfully to characterize cross-border trade in financial assets.[10] 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. Because every pairwise combination in our dataset includes the United States, we modify the model and do not include U.S. GDP in the estimation. We estimate the following equation:

$$\ln(RECEIPTS)_{it} = \beta_0 + \beta_1 \ln(Y_{it}) + \beta_2 \ln(D_i) + \beta_3 \ln(XR_{it}) + \beta_4 \ln(Std(XR_{it})) + \beta_5 \ln(PEG_{it}) + \beta_6 \ln(DIST_i) + \beta_7 \ln(OPEN_{it}) + \beta_8 \ln(CRED_{it}) + \beta_9 \ln(OPEN2_i) + \beta_{10} \ln(INFORMAL_i) + \beta_{11} \ln(MAX\pi_i) + \beta_{12} \ln(\pi_{it}) + \varepsilon_{it}$$

[9] See Anderson and van Wincoop (2003).
[10] See Portes and Rey (2005) and di Giovanni (2005).

where *i* denotes countries and *t* denotes time. The dependent variable is defined as 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*. According to the standard gravity model specification, real GDP should be positively correlated with the size of dollar banknote flows. GDP is an indicator of the total size of economic activity, and all else equal, a larger economy will require more currency for any given purpose.

D_i: the distance between Washington D.C. and the capital city of country *i*. According to the standard gravity model specification, distance should be negatively correlated with the size of dollar banknote flows. Our 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.

XR_{it}: the nominal exchange rate, expressed as units of the currency of country *i* for a single U.S. dollar at time *t*. The exchange-rate relationship is direct and short term – when the dollar appreciates, dollars are worth more relative to the domestic currency, so redemptions should rise, and vice versa for a depreciation. As our exchange-rate variable is measured as units of foreign currency per single U.S. dollar, an increase in the exchange rate is a dollar appreciation, which should lead to a rise in receipts.

$Std(XR_{it})$: the normalized standard deviation of the monthly nominal exchange rate between country *i* and the U.S. for the five years prior to time *t*. The standard deviation of the exchange rate is a measure of macroeconomic volatility, and increased volatility in the domestic currency should encourage adoption of a secondary currency, as it is generally associated with higher expected inflation going forward. We thus expect an increase in this standard deviation to lower receipts, since the currency that is already in the country is more likely to stay there following hoarding by households and businesses.

PEG_{it}: a dummy variable equal to 1 if country *i* is *de facto* pegged to the U.S. dollar at time *t*. Pegging to the U.S. dollar has two primary effects: "importing" U.S. monetary policy, and

actual dollarization of the economy. The model's other variables should reflect any increased macroeconomic stability due to non-autonomous monetary policy, so this variable should identify the effects of dollarization following a peg. We hypothesize that dollarization should increase the use of and so receipts of U.S. dollar banknotes.

$DIST_i$: the distance of the capital city of country *i* from the equator. The distance from the equator measure is used as a proxy for good institutions and for the presence of wholesalers in developing economies and draws on the work of Acemoglu, Johnson and Robinson (2002). Wholesalers are likely to be situated in countries with healthy institutions that can facilitate currency transactions efficiently and securely.[11] Acemoglu, Johnson and Robinson (2002) argue that the correlation between development and distance from the equator is due to the quality of institutions. They propose a measure of European settler mortality as a proxy for whether colonial powers set up growth-oriented institutions in their colonies. While acknowledging that geography is not a direct causal factor, it is in fact correlated with institutions, which allows us to use it as a control variable for unobserved institutional effects. The chief advantage of this measure is that geography is easy to measure, and thus allows us to use the widest possible cross-section.

$OPEN_{it}$: the ratio of exports plus imports to GDP for country *i* at time *t*. If U.S. dollar banknotes are used for large 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, particularly in areas with burdensome regulation, and so may not be counted in the official statistics.

$CRED_{it}$: the ratio of private credit by banks and non-bank financial institutions to GDP for country *i* at time *t*. Our measure of private credit to GDP is a standard measure of financial depth. A country with a better developed banking system is more likely to send and receive currency directly hence increasing observed flows of U.S. currency in our data.

[11] One may suppose, correctly, that this variable should thus also enter our zero-generating process. We find that including it adds no explanatory power to the model: It is highly insignificant.

$OPEN2_i$: the *Heritage Foundation*'s measure of trade freedom for country *i*. This index is a summary measure of total tariff and non-tariff barriers by country. 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 impact of openness on the use of dollar banknotes better than the official trade statistics that comprise $OPEN_i$. We hypothesize that greater trade freedom should be tied to greater use of dollar banknotes.

$INFORMAL_i$: a time-invariant measure of the size of the informal sector relative to average 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.

$MAX\,\pi_{it}$: the maximum inflation rate over the previous 30 years for country *i* at time *t*. One of the primary motivations for adoption of a secondary currency, as noted above, is a significant risk of the government inflating away the value of the domestic currency. Firms and households residing in a country with a history of significant past inflation are more likely to expect high inflation in the future, and so to adopt a secondary currency as a store of value. As most of the variation in our receipts data is cross-sectional, we expect a higher historical inflation rate to increase receipts.

π_{it} : the inflation rate in country *i* at time *t*. One may also expect more recent inflation rates to affect inflation expectations. For this reason, we also include the most recent inflation rate in the empirical model.

ε_{it} : a stochastic error term that is normally distributed.

Figure 3 illustrates the relationship across countries between the log of the country-specific mean of several of these variables and the log of the average receipts flow for each country.

Each data point in the figure denotes a country. We also summarize the expected signs for each variable discussed here and for the coefficients in Equation (6) in Table 2.

5. Results

5.1 Results for the Model of Zero Gross Flows of Dollar Banknotes

Tables 3 and 4 present the results from nine specifications. Table 3 reports the results from our model of zero gross flows of dollar banknotes. The results for the zero-generating process do not differ substantially across the nine specifications, which add additional variables to the gravity model but not the zero-generating process.

The results are reported as elasticities – the change in the probability of observing a zero given a 1-percent change in the independent variable. Recall that the dependent variable is equal to 1 if observed receipts are zero, so a positive marginal effect means a greater probability of observing zero receipts, and vice versa.

The results for real GDP have a straightforward interpretation: a 1-percent increase in real GDP reduces the probability of observing zero receipts by 0.2 to 0.5 percentage points, depending on the specification. For our baseline specification, reported in column (8), a 1-percent increase in real GDP reduces the probability of observing zero receipts by 0.34 percentage points, and doubling per-capita GDP reduces the probability of observing zero receipts by almost one-third.

A 1-percent increase in the highest inflation rate observed over the previous 30 years has an even stronger effect, reducing the probability of observing zero receipts by 0.8 to 1.3 percentage points: Our baseline specification finds a 1-percent increase in this inflation rate reduces the probability of observing zero receipts by 0.84 percentage points, and its doubling reduces the probability of observing zero receipts falls by 70 percent.

The results for the share of trade with the European Union are positive, large, and significant. A 1-percent increase in a country's proportion of trade with the EU increases the probability of observing zero receipts by 0.8 to 1 percentage point, depending on the specification. Our

baseline specification finds that a 1-percent increase in a country's proportion of trade with the EU increases the probability of observing a zero by 0.9 percentage points, and doubling the share of trade with the EU increases this probability by 250 percent.

Finally, credit provided to the private sector has a large, negative, and significant effect on the probability of observing a zero across specifications. A 1-percent increase in a country's credit-to-GDP ratio reduces the probability of observing a zero by 1.20 percentage points in our baseline specification and doubling the share of private credit to GDP reduces the probability of observing zero receipts by over 50 percent.

5.2 Results for the Model of Positive Gross Flows of Dollar Banknotes

Table 4 reports estimation results from our model of positive gross flows of dollar banknotes. All the variables are in logs, so the coefficients can be interpreted as elasticities, that is, as the percentage change in dollar banknote receipts for a 1-percent increase in the independent variable. All the specifications include a constant term whose estimates are not reported. The dependent variable is the gross receipts of banknotes from country *i* to the U.S. in year *t*.

The estimates for the simplest version of the estimating equation (Equation 6 from the end of Section 2) are reported in the first column of Table 4. The distance, size, and exchange-rate variables enter with the expected signs and with well-determined coefficients – all significant at the 1-percent level.

As reported in column (1), a 1-percent increase in a country's real GDP is associated with a 1 percent increase in its receipts. This finding is consistent with the gravity model's prediction that greater economic activity increases the long-run use of dollar banknotes. This coefficient is remarkably stable over the remaining specifications – reaching a maximum of 1.11 percent in our baseline specification in column (8).

The results for our distance measure are also consistent with the standard gravity model result. A 1-percent increase in a country's distance from the U.S. lowers receipts by 1.29

percent in the simplest specification in column (1). This coefficient ranges from about -1.3 to -1.5 percent over the nine specifications we consider.

The response of banknote flows to changes in the nominal exchange rate is also consistent with our predictions: A 1-percent appreciation of the dollar relative to country *i*'s currency results in a 0.20-percent increase in receipts over the course of one year in our simplest specification: this coefficient varies from 0.16 to 0.24 over the remaining specifications. This result is highly intuitive, since it is equivalent to the general advice of "buy low, sell high." A strong dollar can be redeemed for more foreign currency, while a weak dollar can be purchased for less foreign currency. Unlike most of the other variables in our dataset, the identification for this coefficient comes off of time-series rather than cross-sectional variation in the data.

The coefficients on the standard deviation in the bilateral exchange-rate over the previous five years confirm our intuition that some history of macroeconomic volatility makes secondary currency use more attractive, thus reducing receipts. Again, unlike most of the other variables in our dataset, the identification for this coefficient comes off of time-series rather than cross-sectional variation in the data. We find that a 1-percent increase in the standard deviation of the exchange rate over the previous five years is associated with a 0.29-percent decline in receipts in our simplest specification. This coefficient is also quite stable and ranges from -.18 to -.26 over the remaining specifications.

Column (2) reports adds the U.S. dollar peg variable to the simplest specification. As predicted, it is positive, but the coefficient is insignificant, both here and in the remaining specifications. Official dollarization does not appear to increase the use of U.S. dollar banknotes.

The next specification considers the effect of a country's distance from the equator on its banknote flows. As we note in Section 2, this variable proxies for the quality of domestic institutions and so for the presence of wholesalers in developing countries. We find the effect is positive and significant at the 1-percent level, as predicted. A country that is 1-percent

further from the equator has 0.46-percent higher receipts per year. This coefficient is fairly stable across the remaining specifications.

The effect of adding our first openness variable – which is a country's total imports and exports divided by its GDP -- is reported in column (4): This measure is not significant in this or any remaining specification. As we note above, the interpretation of this variable is somewhat tricky. To the extent that trade that uses U.S. dollars is unofficial, higher dollar banknote flows may not be correlated with official trade statistics, as this result suggests.

Adding the credit-to-GDP ratio to the specification, as we do in column (5), has ambiguous effects. Its coefficient is generally positive, and ranges from 0.20 to 0.36, but is generally insignificant, with one exception. This variable is highly correlated with foreign real GDP. When foreign real GDP is not included in the regressions, credit to GDP is large and highly significant for receipts. Thus, in the full model, this variable's marginal significance may be attributable to collinearity with foreign real GDP.

The effect of adding our second openness-to-trade variable, the *Heritage Trade Freedom Index,* is reported in column (6): The coefficient is large, positive, and significant. Across the remaining specifications, a 1-percent increase in this index translates into a 3-4 percent increase in receipts.

Turning to the next column, one sees that a large informal sector is associated with higher dollar receipts, which implies greater use. A 1-percent larger informal sector-to-GDP ratio implies 1.4-percent greater receipts per year in this specification, and 1.6 to 1.7 percent higher receipts in the final two specifications. This confirms our hypothesis that a large unofficial sector creates more opportunities for households and businesses to adopt the use of dollars as both a means of exchange and a store of value.

Moving to the final group of variables and the specifications in columns (8) and (9), one sees that the maximum annual inflation rate observed over the previous 30 years has a negative and significant coefficient, at -0.21, which implies that a 1-percent increase in this rate

lowers receipts by about 0.2 percent. This historical inflation rate appears more important as a driver of the inflation expectations that cause households and businesses to adopt a secondary currency than the more recent inflation rate. The coefficient on the latter is not significant, as reported in column (9).

These results are all robust to the inclusion of time dummies. For our baseline specification, we do not have measures of fit comparable to an R^2 available to us for the negative binomial model. But when we run the model using ordinary least squares, to be comparable with most of the previous results in the literature, we find that our model captures almost 50 percent of the variance in bilateral cross-border currency flows, which is comparable to the goodness of fit found for gravity models of both goods (e.g. Anderson and van Wincoop, 2003) and financial assets (e.g. Portes and Rey, 2005).

5.3 Alternative Results for the Model of Positive Gross Flows of Dollar Banknotes

Remittance payments provide another channel by which foreign currencies enter the economy, and thus represent a substitute for official dollar banknote operations. We expect larger remittance inflows to be associated with higher receipts and lower payments. Note that because the data on remittances cover many fewer countries than does our full sample, we estimate the model separately with remittance payments. Table 5 reports the estimation results for both the zero-generating process and the gravity model when the remittance data are included. We find that a 1-percent higher level of remittance inflows is associated with 0.16-percent higher receipts, which confirms our original prediction that remittance credits should increase observed receipts of dollar banknotes. The coefficients on the other variables remain substantially unchanged with the inclusion of the remittances data.

6. Conclusion

This paper characterizes the determinants of flows of physical U.S. currency across countries. Our findings both complement and extend the existing literature on the use of secondary currencies. We find that a country's use of dollar banknotes 1) increases with its real GDP and decreases with its distance from the U.S.; 2). A dollar appreciation reduces the use of dollars banknotes over the course of one year; 3). A history of unusual exchange-rate

volatility or high inflation raises the use of dollar banknotes; 4). A large informal sector raises the use of dollar banknotes; 5). A high proportion of trade with the EU lowers the use of dollar banknotes; 6). Official trade flows do not have a significant relationship to the use of dollar banknotes.

A major challenge for future research is to examine the short-run demand for dollars in crisis periods. In future work, we plan to look at higher frequency models that may be more applicable to such periods of financial turmoil. We also plan to examine the implications of our findings for the international role of the dollar going forward. The financial crisis of 2008 has raised questions about the use of the dollar in international transactions. In addition, as the Federal Reserve now pays interest on reserves, the seigniorage it earns from currency in circulation is a major source of its revenue. Thus, assessing the country-level determinants of use of U.S. cash dollars may have implications for the Federal Reserve's balance sheet in the future.

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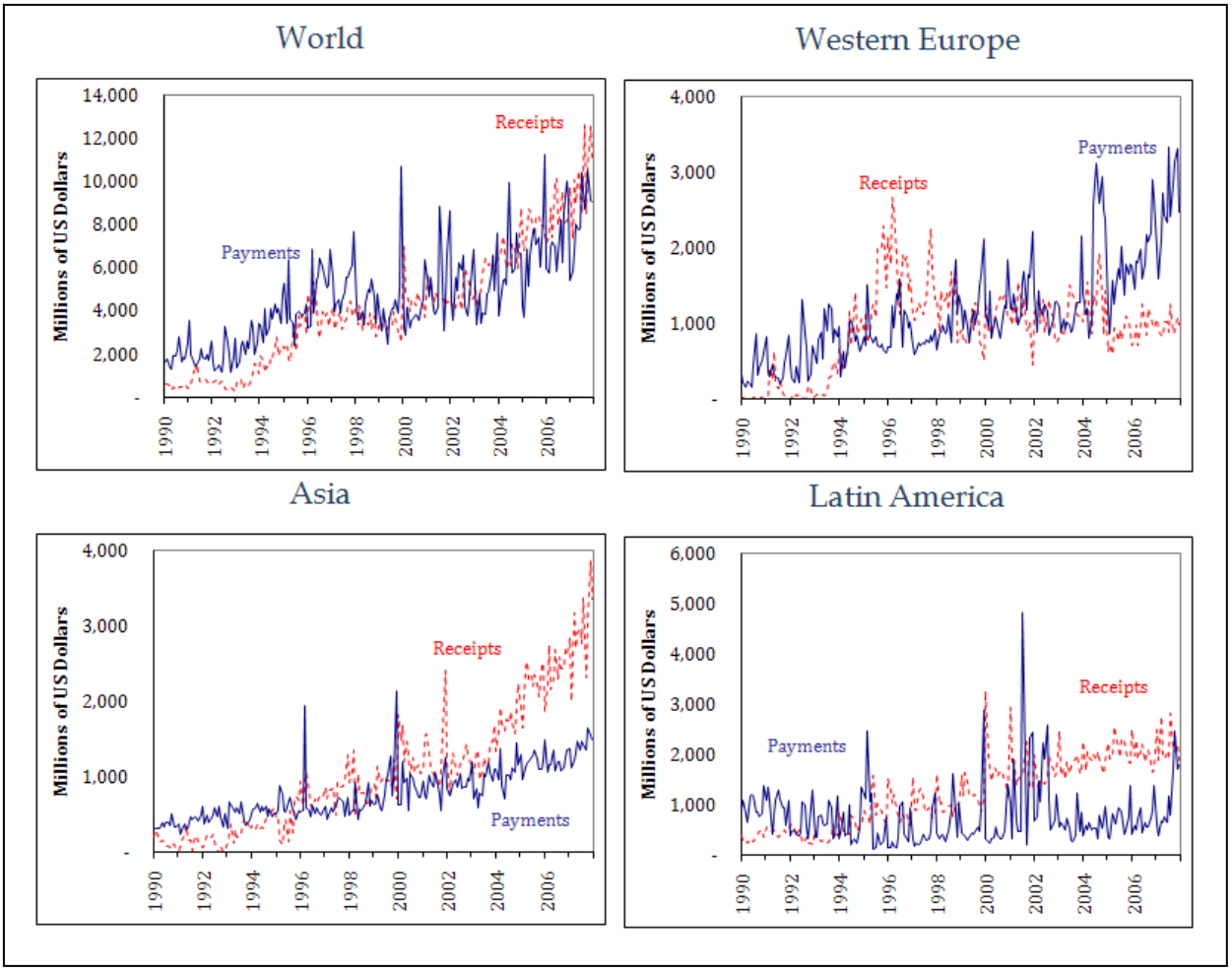

Figure 1: *Monthly Payments and Receipts of U.S. Dollar Banknotes, 1990-2007*. Source: *Federal Reserve System.*

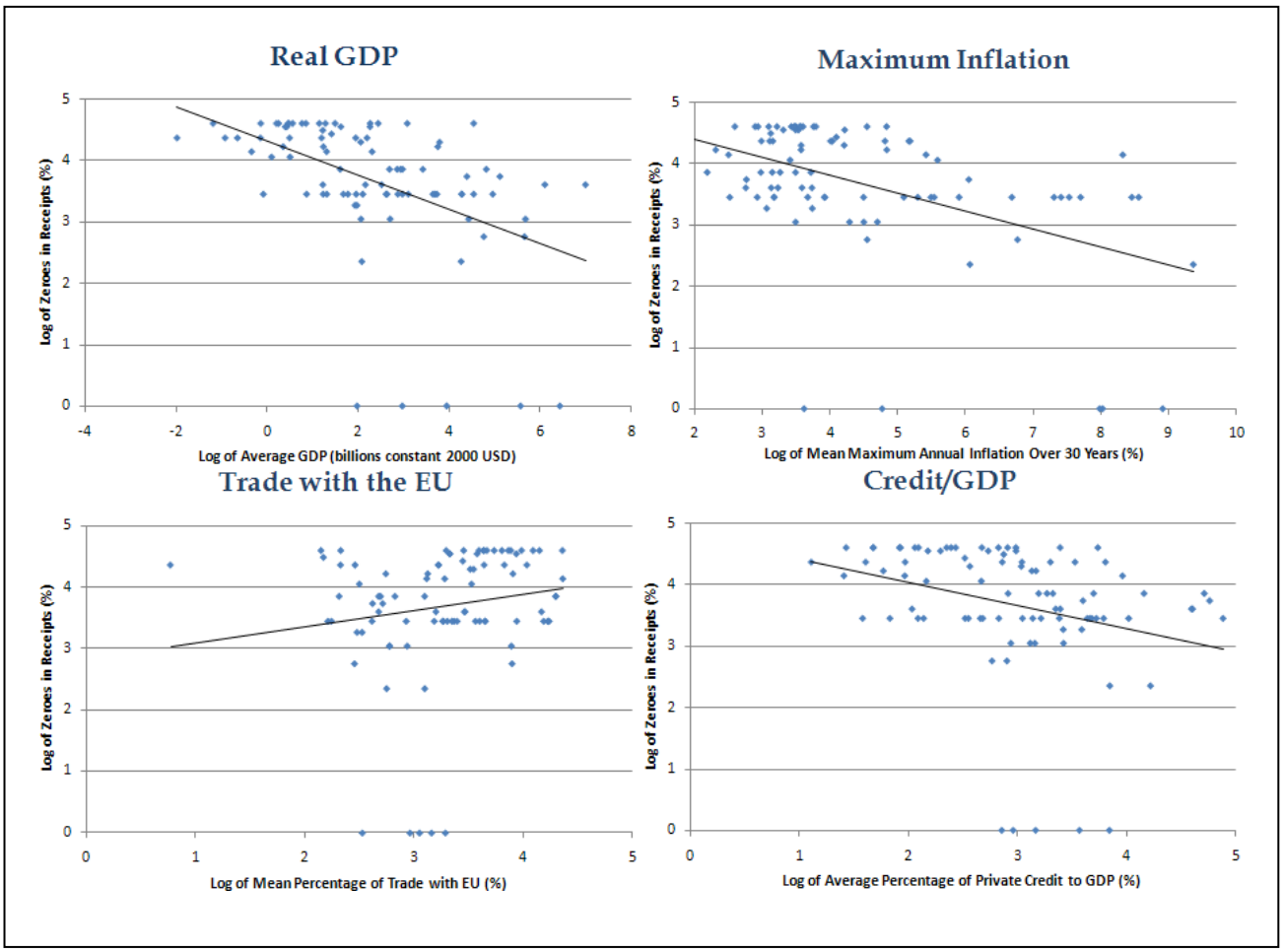

Figure 2: *Correlations of Selected Variables with Zero Dollar Receipts.* Gives the log of the average value of each variable plotted against the log of the percentage of zero dollar observations in receipts. Each data point represents a country. Sources: *Federal Reserve System, World Bank, International Monetary Fund.*

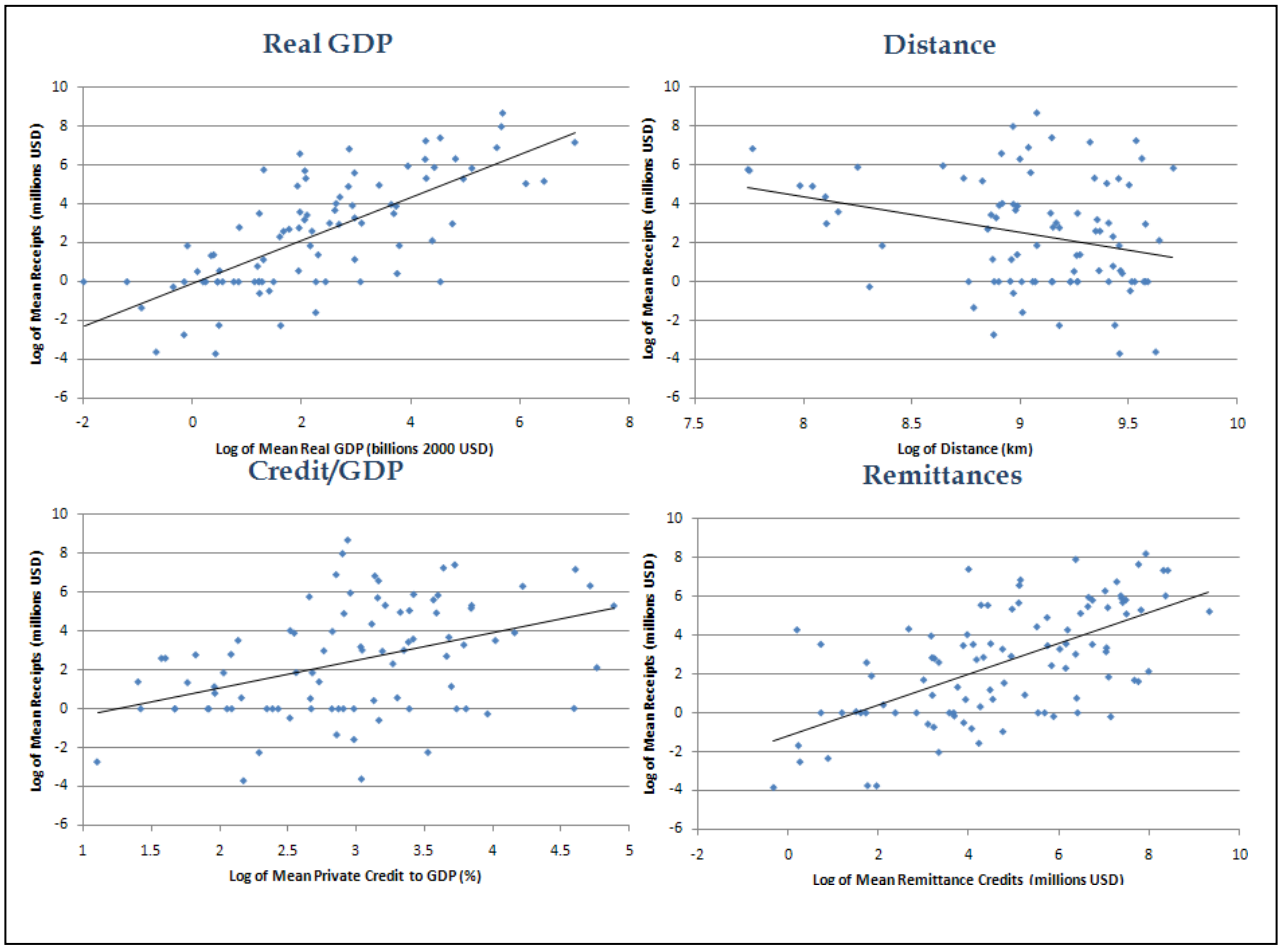

Figure 3: *Correlation of Selected Variables with Dollar Receipts.* Gives the log of the average value of each variable plotted against the log of the average size of dollar receipts over the sample period. Each data point represents a country. Sources: *Federal Reserve System, World Bank, International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

Table 1: Summary Statistics

Description	Mean	Standard Deviation	Min	Max
Receipts (millions USD)	222.3	967.7	0.0	19,686.7
Real GDP (billions constant 2000 USD)	55.9	161.5	0.1	2,113.0
Capital City Distance from Washington DC (km)	9,243.0	3,441.8	2,312.2	16,370.8
Nominal Exchange Rate (Foreign/USD)	505.6	1,608.2	0.0	15,518.3
Standard Deviation in the Exchange Rate (past 5 years)	0.1	0.9	0.0	13.4
USD Peg Indicator (=1 if true) (%)	0.2	0.4	0.0	1.0
Size of the Informal Sector (% of official GDP)	41.0	11.4	15.6	68.3
Distance from the Equator (absolute degrees latitude)	21.5	15.7	0.0	59.0
Proportion of Trade to GDP (%)	78.3	41.0	10.8	275.2
Heritage Foundation Trade Freedom Measure	74.0	13.1	0.0	95.0
Private Credit to GDP (%)	28.4	27.9	0.7	165.7
Proportion of Trade with the EU (%)	31.9	19.7	0.0	92.3
Highest Annual Inflation Previous 30 Years (%)	596.2	1,757.1	0.4	11,749.6
Inflation Rate (%)	22.1	101.7	-11.7	2,110.5
Remittance Credits (millions USD)	879.9	2,110.1	0.0	25,108.9

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

Empirical Variable	Receipts	Zero Receipts	Theoretical Variable
Foreign Economy's Real GDP	+	-	S
Distance	-		a_1
Bilateral Nominal Exchange Rate (Units of Foreign Currency/USD)	+		ε, π^e
Standard Deviation in Exchange Rate Over Previous Five Years	-		ε, π^e
USD Peg Indicator	+		a_1
Distance from the Equator	+		a_1
Openness to Trade	+		a_1
Private Credit/GDP	+	-	a_1
Heritage Index - Trade Freedom	+		a_1
Size of Informal Sector	+		π^e, a_1
Proportion of Trade with the European Union		+	a_1
Highest Annual Inflation Rate Over Past 30 Years	+	-	π^e
Inflation Rate	+		π^e
Remittance Credits	+		a_1

Table 3: Zero-Inflation Model for International Cash Flows, 1990 to 2007

Variable	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Foreign Economy's Real GDP	-0.22	-0.19	-0.16	-0.20	-0.20	-0.21	-0.35	-0.34	-0.49
	[0.13]	[0.14]	[0.13]	[0.15]	[0.14]	[0.15]	[0.18]*	[0.16]**	[0.20]**
Maximum Annual Inflation (Previous 30 Years)	-1.16	-1.34	-1.30	-1.31	-1.30	-1.27	-0.87	-0.84	-0.92
	[0.28]***	[0.30]***	[0.31]***	[0.32]***	[0.31]***	[0.32]***	[0.46]*	[0.41]**	[0.53]*
Proportion of Trade with the European Union	1.02	0.94	0.93	0.96	0.95	0.94	0.95	0.89	0.78
	[0.41]**	[0.39]**	[0.39]**	[0.40]**	[0.40]**	[0.40]**	[0.41]**	[0.37]**	[0.38]**
Private Credit/GDP	-1.34	-1.53	-1.52	-1.41	-1.36	-1.21	-1.22	-1.20	-1.26
	[0.33]***	[0.36]***	[0.37]***	[0.41]***	[0.42]***	[0.43]***	[0.34]***	[0.30]***	[0.37]***
Log Pseudolikelihood	-5201	-5020	-4984	-4866	-4864	-4843	-4555	-4542	-4279
Observations	1517	1485	1467	1435	1435	1418	1283	1283	1148

Notes: Standard errors in brackets. Starred coefficients are significant at the *10-,**5-, or ***1-percent level.

Table 4: Gravity Model for International Cash Flows, 1990 to 2007

Variable	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Foreign Economy's Real GDP	1.02	1.09	1.05	1.06	1.02	1.00	1.09	1.11	1.08
	[0.12]***	[0.12]***	[0.12]***	[0.12]***	[0.13]***	[0.12]***	[0.13]***	[0.11]***	[0.11]***
Distance	-1.29	-1.53	-1.47	-1.48	-1.46	-1.39	-1.36	-1.36	-1.31
	[0.33]***	[0.34]***	[0.31]***	[0.30]***	[0.30]***	[0.28]***	[0.28]***	[0.28]***	[0.28]***
Bilateral Nominal Exchange Rate (Foreign/USD)	0.20	0.17	0.20	0.19	0.19	0.16	0.24	0.21	0.21
	[0.06]***	[0.08]**	[0.07]***	[0.08]**	[0.08]**	[0.07]**	[0.08]***	[0.07]***	[0.07]***
Standard Deviation in XR Over Previous 5 Years	-0.29	-0.26	-0.24	-0.24	-0.22	-0.19	-0.22	-0.20	-0.18
	[0.05]***	[0.05]***	[0.06]***	[0.06]***	[0.06]***	[0.06]***	[0.06]***	[0.06]***	[0.08]**
USD Peg Indicator		0.56	0.71	0.60	0.62	0.59	0.16	0.36	0.36
		[0.44]	[0.49]	[0.50]	[0.47]	[0.47]	[0.54]	[0.50]	[0.55]
Distance from the Equator			0.46	0.44	0.45	0.33	0.43	0.47	0.51
			[0.16]***	[0.18]**	[0.17]***	[0.18]*	[0.18]**	[0.16]***	[0.17]***
Openness to Trade				0.11	0.03	-0.06	0.04	-0.14	-0.10
				[0.37]	[0.36]	[0.33]	[0.30]	[0.28]	[0.30]
Private Credit/GDP					0.20	0.31	0.36	0.24	0.21
					[0.20]	[0.20]	[0.21]*	[0.19]	[0.21]
Heritage Index - Trade Freedom						2.99	3.08	4.12	4.07
						[1.18]**	[1.33]**	[1.10]***	[1.12]***
Size of Informal Sector							1.42	1.71	1.64
							[0.59]**	[0.54]***	[0.57]***
Maximum Annual Inflation (Previous 30 Years)								-0.21	-0.20
								[0.07]***	[0.07]***
Inflation Rate									-0.14
									[0.17]
Log Pseudolikelihood	-5201	-5020	-4984	-4866	-4864	-4843	-4555	-4542	-4279
Observations	1517	1485	1467	1435	1435	1418	1283	1283	1148

Notes: Standard errors in brackets. Starred coefficients are significant at the *10-,**5-, or ***1-percent level.

Table 5. Gravity Model with Remittances, 1990 to 2007

Variable	Zero Receipts	Positive Receipts
Foreign Economy's Real GDP	-0.29	0.98
	[0.16]*	[0.14]***
Distance		-1.08
		[0.27]***
Bilateral Nominal Exchange Rate (Foreign/USD)		0.17
		[0.09]*
Standard Deviation in XR Over Previous 5 Years		-0.12
		[0.07]*
USD Peg Indicator		0.80
		[0.53]
Distance from the Equator		0.44
		[0.16]***
Openness to Trade		-0.01
		[0.35]
Private Credit/GDP	-1.11	0.23
	[0.36]***	[0.23]
Heritage Index - Trade Freedom		3.98
		[1.29]***
Size of Informal Sector		1.51
		[0.70]**
Maximum Annual Inflation (Previous 30 Years)	-1.45	-0.14
	[0.36]***	[0.10]
Remittances		0.16
		[0.08]**
Proportion of Trade with the EU	0.87	
	[0.38]**	
Log Pseudolikelihood	-3438	-3438
Observations	855	855

Notes: Standard errors in brackets. Starred coefficients are significant at the *10-,**5-, or ***1-percent level.

Appendix 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

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

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

$$g\left(\frac{\varepsilon_s M_F}{P_{F,s}} \right) = a_0 \left(\frac{\varepsilon_s M_F}{P_{F,s}} \right) - \frac{a_1}{2} \left(\frac{\varepsilon_s M_F}{P_{F,s}} \right)^2 \tag{.2}$$

where $1-\beta < a_0 < 1, a_1 > 0$ 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

$$B_{t+1} + \frac{M_{H,t}}{P_{H,t}} + \frac{\varepsilon_t M_{F,t}}{P_{H,t}} = \left(1+r\right) B_t + \frac{M_{H,t-1}}{P_{H,t}} + Y_t - C_t - T_t \tag{.2}$$

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

$$u'(C_t) = u'(C_{t+1})$$

(.2)

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

(.2)

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

(.2)

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:

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

(.2)

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

$$\frac{M_{F,t}}{P_{F,t}} = \frac{1}{a_1}(a_0 - A) \text{ where } A = \frac{1 - \frac{\beta}{\pi_F^e}}{1 - \frac{\beta}{\pi_H^e}}$$

(.3)

$$M_{F,t} = \frac{1}{a_1}(a_0 - A_t) P_{F,t} = \frac{1}{a_1}(a_0 - A_t) \frac{P_{H,t}}{\varepsilon}$$

(.4)

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

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

$$\ln L = \sum_{j \in S} \ln\left[F\left(\mathbf{z}_j \gamma\right) + \left\{1 - F\left(\mathbf{z}_j \gamma\right)\right\} p_j^m \right] + \sum_{j \notin S} \begin{bmatrix} \ln\left\{1 - F\left(\mathbf{z}_j \gamma\right)\right\} + \ln\Gamma\left(m + y_j\right) - \ln\Gamma\left(y_j + 1\right) - \\ \ln\Gamma\left(m\right) + m \ln p_j + y_j \ln\left(1 - p_j\right) \end{bmatrix}$$

$$m = \frac{1}{\alpha}$$

$$p_j = \frac{1}{\left(1 + \alpha e^{\mathbf{x}_j \beta}\right)}$$

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 α is the overdispersion parameter (equal to 0 if the process is Poisson).