LOCAL AND GLOBAL DETERMINANTS OF INTERNATIONAL DEMAND FOR U.S. BANKNOTES

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Unlike the banknotes of most other countries, the U.S. dollar is extensively used far beyond its borders as a medium of exchange and store of value. As a result, demand for U.S. dollars is driven by both international and domestic developments. Prior to 2007, episodes of unusually high demand for dollars seemed to correspond to periods of economic or political crisis in specific regions or countries, particularly Argentina and the former Soviet Union. During such episodes, dollar flows to the country in crisis would show sharp increases, and, in the case of larger countries such as Argentina or Russia, these increases in demand would be large enough to dominate overall U.S. currency growth. But in recent years, currency growth has been exceptionally strong even in times when severe crisis in particular countries was not particularly evident. Of course, this period was dominated by extreme uncertainty associated with the global financial crises centered first in the United States and later in Europe.

In this paper, we examine the local and global factors driving international demand for U.S. banknotes. In particular, we attempt to quantify the relationship between dollar banknote flows between the United States and other countries using both country-specific and global factors.

Understanding the factors driving international dollar usage has important implications for a wide range of Federal Reserve operational considerations, including daily open market operations, management of the Federal Reserve's portfolio, analysis and forecasting of the Federal Reserve's income, the interpretation of currency figures as part of monetary analysis, and currency design, production, processing, and planning. In addition, currency exports, like other exports, figure in the U.S. balance of payments and international investment position.

To address our question we use an internal confidential and rarely used panel dataset of commercial bank shipments between the United States and other countries from the Federal Reserve System.

Our paper is related to a vast body of theoretical work that studies the use and determinants of secondary currencies as well as work that develops estimates of external dollar and euro circulation. At the global level, we find that the measures of uncertainty and standard macro variables explain somewhat less than half of the variation in the data since 2000, but that the relative significance of these variables is very different after 2008 than before. When the sample is split into two periods, the overall explanatory power increases significantly. In country-level panel regressions, we find that both global and local factors—including prior use of dollars in the country—play a role in demand for U.S. dollars.

JEL Classifications: F39 (International Finance-Other); E41 (Demand for Money); E42 (Monetary Systems)

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I. Introduction / Overview

Unlike the banknotes of most other countries, the U.S. dollar is extensively used far beyond its borders as a medium of exchange and store of value. As a result, demand for U.S. dollars is driven by both international and domestic developments.[3] Prior to 2007, episodes of unusually high demand for U.S. dollars seemed to correspond to periods of economic or political crisis in specific regions or countries, particularly Argentina and the former Soviet Union. During such episodes, available measures of dollar flows to the country in crisis would show sharp increases; in the case of larger countries such as Argentina or Russia, these increases in demand would be large enough to dominate overall U.S. currency growth. But in recent years, currency growth has been exceptionally strong even in times when severe stress in particular countries was not particularly evident. This new scenario of exceptionally strong demand for US dollars in an environment dominated by extreme global uncertainty associated with the financial crises, centered first in the United States and later in Europe, raised the question about the role of global developments as determinants of international demand for U.S. dollars.

In this paper, we attempt to quantify the influence of both local and global factors driving international demand for U.S. banknotes since 2000. In particular, we explore the relationship between dollar banknote flows to and from the United States and other countries using country-specific and global factors. To address our question, we use an internal and confidential panel

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[3] In this work, "U.S. dollars" and "dollars" refers to physical banknotes rather than dollar-denominated assets. The vast majority of U.S. dollar banknotes in circulation are Federal Reserve notes.

dataset of commercial bank shipments between the United States and other countries. Our dataset covers monthly payments and receipts for a large set of countries from around 1990 to the present.[4] Specifically, we analyze net shipments, which a difference between payments and receipts, for aggregate data and for a panel of countries.

From the domestic perspective, understanding the factors driving international dollar usage has important implications for a wide range of Federal Reserve operational considerations and exit strategies from the quantitative easing programs, including daily open market operations and potential large-scale liquidity draining operations, the management of the Federal Reserve's portfolio, analysis and forecasting of the Federal Reserve's income, the interpretation of currency figures as part of monetary analysis, and planning for currency production and distribution. In addition, currency exports, like other exports, figure in the U.S. balance of payments and international investment position.

From the international perspective, we would like to understand the importance of global and local factors determining the demand for U.S. currency. It may appear that local factors are more important than global factors. For example, demand for U.S. currency was extremely strong through the 1990s, a period of turmoil for the former Soviet Union and for Argentina, two of the largest overseas users of U.S. currency, and then eased in the early 2000s as conditions gradually stabilized and as financial institutions developed. However, more recently, it appears that global factors took over: this trend of the weakening demand reversed sharply with the onset of the financial crisis in late 2008 and has continued since then.

[4] Although this dataset begins in the late 1980s, we focus on the period 2000 to 2013 due to limitations in data quality and coverage in the early part of the sample.

Our paper is related to a vast body of theoretical work that studies the use of secondary currencies in cash as well as noncash form, such as bank deposits.[5] On the empirical side, several studies have presented estimates of external dollar and euro circulation, including Judson (2012), Doyle (2000), Feige (2012), Porter and Judson (1996), Judson and Porter (2001), Stix (2010), Fischer et al. (2004), and Bartzsch et al. (2011, 2013). Finally, Hellerstein and Ryan (2011) find that factors such as the highest inflation rate over the previous 30 years, the level of trade, trade barriers, and a measure of the degree of competition between the U.S. dollar and the euro as a secondary currency can be helpful in explaining international demand for U.S. banknotes.

The remainder of this paper proceeds as follows. In the next section, we present a very brief overview of the significance of currency for Federal Reserve operations, and we then review the data available and the challenges of measuring dollar usage outside the United States. In Section IV, we place this work in the context of other work on external U.S. dollar usage and flows. In Section V, we present aggregate regressions that demonstrate the link between global factors and demand for U.S. currency; we find that global factors can explain about half of the monthly variation in net payments of currency over our sample. We also show that shipments to a very small number of countries dominated total shipments before the crisis, but not afterward. In Section VI, we present country-level regressions that include both global and country-specific explanatory variables. We find that, for countries that have seen significant dollar demand, both local and global variables are correlated with dollar flows, with the contribution of global factors generally much stronger in the period since late 2008. In Section VII, we conduct a brief exercise to estimate the impact of various trajectories for currency growth on the implementation of U.S.

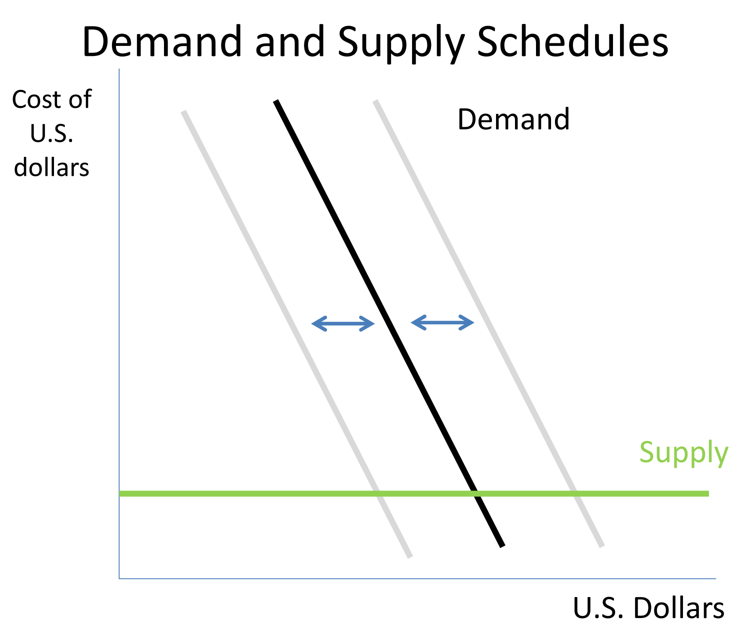
[5] See, for example Kamin and Ericsson (2003).

monetary policy. The final section concludes and provides some directions for further work on this topic.

II. The Role of Currency in Federal Reserve Operations and Available Data

A. Currency in Federal Reserve Operations

Understanding the demand for currency has consistently played an important role in Federal Reserve operations, both in the logistical planning needed to supply banknotes of high quality in adequate quantities and in the implementation of monetary policy. On the operational side, the Federal Reserve is responsible for overseeing or implementing a wide array of tasks related to the production, distribution, use and destruction of Federal Reserve notes. The Federal Reserve issues and processes Federal Reserve notes. In fact, the Federal Reserve supplies Federal Reserve notes—U.S. currency—elastically at a very low transaction cost which has not changed much over the years, so the data on notes shipments identifies demand for these notes.



In addition, each year, the Federal Reserve Board determines the number of new Federal Reserve notes that are needed and submits a print order to the Treasury's Bureau of Engraving and Printing (BEP). The Federal Reserve works with the Treasury's BEP to determine banknote design and production schedules. The Federal Reserve is then responsible for the storage, distribution, processing, and destruction of currency at its offices. The Federal Reserve also determines policies for banknote handling by commercial banks, and, in cooperation with the Treasury, provides public education as necessary. Finally, the Federal Reserve works with the Treasury and the United States Secret Service to monitor and reduce counterfeiting.

Somewhat less obviously, understanding currency demand is relevant to monetary policy implementation even though currency is only a small part of the most commonly-referenced monetary aggregate, M2, and even though the Federal Reserve has not focused on the money supply as a policy variable for several decades. From the 1990s until late 2008, the Federal Reserve's primary policy tool was the federal funds rate, for which the target was set by the Federal Open Market Committee (FOMC). Staff at the Federal Reserve, primary at the Federal Reserve Bank of New York and the Federal Reserve Board, implemented monetary policy by adjusting the quantity of reserve balances each day in order to influence the daily federal funds rate. Determining the desired level of balances was a multifaceted exercise of which an important part was forecasting daily changes in the demand for currency. During this period, currency was the primary liability on the Federal Reserve's balance sheet, shown in green in Figure 1A, and changes in currency demand were a major consideration in the conduct of daily open market operations as well as in longer-range planning related to the Federal Reserve's System Open Market Account portfolio.[6] After late 2008, deposits of depository institutions at the Federal Reserve, shown in gray in Figure 1B, increased significantly and now exceed currency as a liability on the Federal Reserve's balance sheet. Looking ahead, forecasts of

[6] For additional details, see the Federal Reserve's *Purposes and Functions* (2013).

currency demand are an important input into planning for the Federal Reserve's exit from its current asset purchase programs and, ultimately, balance sheet "normalization," a topic that we will address more fully in Section VII.

III. Data on Cross-Border Flows of U.S. Currency

Data on cross-border flows of U.S. currency are available from two sources: U.S. Customs and the Federal Reserve. While neither of these sources is perfect, the Federal Reserve dataset, our primary source, is richer and more informative of the two sources.

1. U.S. Customs Data

In principle, the most obvious direct source of information on U.S. currency flows across U.S. borders should be the Currency and Monetary Instrument Reports (CMIRs), which are compiled by the U.S. Customs Service. Individuals and firms making almost any shipment of more than $10,000 in cash across a U.S. border are required to file CMIRs, so these reports should be quite comprehensive and informative. However, as noted in Treasury (2006), CMIRs are neither accurate nor thorough measures of large cash shipments outside the banking sector due to three shortcomings: a generally one-sided system for collecting data, the omission of some potentially large volumes of currency flows, and the inability to accurately reflect flows to international custodial holding sites for U.S. currency.

First, all individuals entering or leaving the United States are required to complete a CMIR if they are carrying more than $10,000 in currency or monetary instruments. In practice, though, customs formalities, including a specific question about currency and monetary instruments, are required for individuals entering the United States, but not for individuals exiting the United States.[7] As a result, it seems plausible that underreporting is more likely for outbound travelers.

Second, even if all travelers were to report accurately, the CMIRs require no reporting for sums below $10,000; in aggregate, these sums could be considerable. In 2009, 151 million passengers arrived and departed on international flights at U.S. airports and about 200 million border crossings occurred by land in 2009 (U.S. Census 2012). The net movements of currency across U.S. borders through such nonbanking channels are potentially significant. Indeed, as noted in U.S. Treasury (2006), customs reporting for Mexico indicates substantial cash flows from the United States to Mexico in the hands of tourists and migrants; such flows, since they typically occur in amounts of less than $10,000 and through nonbanking channels, are not captured in U.S. data.

Third, the CMIRs do not account properly for shipments to international custodial holding sites for the U.S. currency. These sites, known as Extended Custodial Inventories, or ECIs, are secure locations outside the United States at which U.S. currency is held in custody for the Federal Reserve Bank of New York. Shipments to these sites are recorded in U.S. Customs data when they physically exit the United States, even though they remain in the custody of the Federal Reserve Bank of New York. Thus, for example, a shipment to an ECI in Switzerland will be recorded as a shipment to Switzerland on the day it occurs even though the currency is not in circulation.[8]

In addition to these three shortcomings for the CMIR data's coverage of overall flows, the CMIR data's country attribution is problematic. CMIR reporting requires only information

[7] Passengers on flights departing the United States are sometimes questioned or informed about this reporting requirement, but coverage is far from complete.

[8] Refer to U.S. Treasury (2006), Chapter 5, for more details about ECIs.

about the immediate source or destination of currency flows, not the ultimate source or destination like the commercial bank shipment data. For example, if an institution ships currency to Russia via Germany, the commercial bank shipment data from a reporting institution would record the destination as Russia while the CMIR data would report the destination as Germany. We therefore consider the shipments data described above to be superior to the CMIR data, and hence we do not use the CMIR data in this study.[9]

2. Federal Reserve Commercial Bank Shipment Data

The primary dataset we use in this work is a monthly dataset on monthly net shipments of U.S. dollar banknotes between the United States and other countries. The Federal Reserve provides currency on demand to all account holders, including those who provide banknotes to international customers. Many of these institutions, including most of the largest wholesale banknote dealers, report, on a voluntary and confidential basis, the value and ultimate source or destination country of their receipts and payments of U.S. currency. While not all banks that deal in the international shipment of banknotes provide these reports, the banknote shipping business is highly concentrated and this dataset currently captures the vast majority of banknote shipments that cross U.S. borders through commercial banking channels. These data are not available elsewhere, and have been used at the country level only once before.[10]

[9] For researchers who do not have access to the shipment data, or for certain countries and time periods, the CMIR data can provide useful insights. Refer, for example, to Feige (1996, 2012) for analysis of the U.S. economy and to Kamin and Ericsson (2003) for analysis of dollarization in Argentina. For the latter analysis, CMIR data were both available over a longer time period and more reliable than usual because of the patterns of dollar flows to Argentina.

[10] Hellerstein and Ryan (2011) is the only previous work using these data at the country level. The aggregate data, however, have been used in previous work; see, for example, Porter and Judson (1996), Judson and Porter (2001), and Judson (2012).

This dataset begins in the late 1980s and covers virtually every country in the world. The quality of the data varies across time as the set of reporting dealers has evolved; for all practical purposes, the dataset begins in the mid-1990s. The level of detail in the reporting has generally improved over time as more dealers have begun to report, but the trend can reverse if, for example, a reporting banknote dealer leaves the banknote business and other nonreporting dealers begin providing banknote shipment services to the departing reporter's customers. In general, though, reporting dealers comprise the vast majority of the reporting in this dataset in recent years.

Although this dataset is unique and rich, the data must be interpreted with some care because of three shortcomings. First, as noted above, the dataset does not always provide the ultimate source or destination of currency movements, especially when the shipments are executed by nonreporting dealers. For example, consider a shipment bound for Russia via Germany. The immediate source or destination of the shipment can be identified by the location of the counterparty. Thus, for a nonreporting dealer, the dataset would only indicate a shipment to Germany, but a reporting dealer would provide the ultimate destination, Russia. Conversely, consider a shipment from Cambodia back to the United States via Hong Kong. Data from a nonreporting dealer would indicate an inflow of dollars to the United States from Hong Kong, but data from reporting dealer would indicate the ultimate source of shipment as Cambodia.

The two other shortcomings of this dataset are that it covers only banknote flows to and from the United States, and that it only covers flows through the banking system. First, the dataset does not cover U.S. banknote flows among other countries, which can be substantial, especially in areas where large volumes of cross-border trade are conducted in cash.[11] The

[11] Refer to U.S. Treasury (2006) for examples of such flows.

absence of such information complicates any estimation of regional or country-level holdings or flows outside the United States, but does not affect aggregate measurements of commercial bank currency shipment flows into and out of the United States. However, banknote flows through nonbank channels can also be significant, and observations gathered in the course of the joint U.S. Treasury – Federal Reserve International Currency Awareness Program (ICAP) indicate that several countries receive dollar inflows through nonbank channels such as tourists or migrant workers but return the currency to the United States through banking channels.[12] As a result of these shortcomings and complications, the country-level data must be interpreted with care and with an understanding of the institutional arrangements in place through time.

B. Total Currency in Circulation

1. Public Data

In general, the aggregate quantity of genuine currency in circulation is relatively easy to measure: it is physical, and it is produced, transported, and issued under very secure conditions.[13] Official currency statistics for the United States are reported by the Treasury and Federal Reserve, which collaborate to produce data on currency in circulation, generally defined as Federal Reserve notes, Treasury currency, and coin held outside of the vaults of the Federal Reserve and the Treasury.[14] Figures on total currency in circulation are reported weekly on the Federal Reserve's H.4.1 and H.6 Statistical Releases; the quarterly *Treasury Bulletin* provides additional detail on denominations of banknotes and coin in circulation.

[12] This phenomenon is addressed in more detail in the discussion of the flow data.

[13] The quantity of counterfeit currency in circulation at any point is not known, but estimates suggest that circulating counterfeits are extremely small relative to genuine currency, on the order of one to three in 10, 000 (Judson and Porter (2010)).

[14] Appendix table 1 provides a list of sources of currency data along with a description of the different definitions of currency.

2. Internal Data

The Federal Reserve's internal accounting and production processes require close monitoring of currency production, processing, and movements; as a result, more frequent and detailed data are available internally for Federal Reserve notes, which constitute the vast majority of currency in circulation ($1.20 trillion of the $1.24 trillion total as of the end of 2013).[15] In particular, accounting data provide daily updates by denomination on the quantity of Federal Reserve notes outstanding (that is, carried on the books of each Federal Reserve Bank), and in the custody of each Federal Reserve Bank. In addition, processing data provide monthly totals of Federal Reserve note movements between each Federal Reserve office and circulation by denomination.[16] As shown in Judson (2012), these data and simplifying assumptions about domestic and international movements of banknotes can be exploited to obtain estimates of stocks and flows of U.S. currency abroad.

IV. Previous work on external U.S. dollar usage and flows

On the empirical side, several studies have presented estimates of external dollar and euro circulation, including Judson (2012), Doyle (2000), Feige (2012), Judson and Porter (1996, 2001), Stix (2010), Fischer et al. (2004), and Bartzsch et al. (2011, 2013) . For example, Judson (2012) finds that once a country or region begins using dollars, subsequent crises result in additional inflows and that economic stabilization and modernization appear to result in reversal of these inflows.

[15] H.4.1 Statistical Release, tables 1 and 8. http://www.federalreserve.gov/releases/h41/20131226/.

[16] The locations and boundaries of the twelve Federal Reserve districts were set when the Federal Reserve was established in 1913. Within each district, cash processing occurs at one or more cash offices. The number and location of these offices varies over time. Processing data are reported separately for each office.

Because Hellerstein and Ryan (2011) use the same data as we do, we will address the differences between this paper and their work in more detail. Hellerstein and Ryan (2011) find that factors such as the highest inflation rate over the previous 30 years, the level of trade, trade barriers, and a measure of the degree of competition between the U.S. dollar and the euro as a secondary currency can be helpful in explaining international demand for U.S. banknotes.[17] There are several major differences between their approach and ours: the choice of the left-hand-side variable, the regression models, the frequency of the data, the time period, and, ultimately, the research question.

In contrast to Hellerstein and Ryan (2011)'s modeling of receipts of U.S. banknotes from commercial bank shipments, we use net shipments (shipments of currency from the United States to other countries, or payments, less shipments of currency from other countries to the United States, or receipts) as the dependent variable, which we believe to be a more relevant metric. For example, consider a country for which receipts are zero but payments are large. In Hellerstein and Ryan's model, such a country is not classified as a U.S. dollar user until a moment the currency once shipped to this country gets returned to the United States.[18] Note that an important reason for the circulation of U.S. currency abroad is its use as a store of value. Currency used as a store of value might be hoarded for an extended period before it enters circulation for transactional purposes. Even if it is used for transactional purposes soon after it is shipped, such currency is likely to circulate for several years before it requires replacement. Thus, a lag likely exists between the time at which store-of-value demand increases—for example, in the early

[17] Hellerstein and Ryan (2011) focus on the period from 1990 to 2007, and use annual data on receipts of U.S. banknotes from commercial bank shipments to model receipts along two margins: the extensive margin, capturing whether the receipts are observed or not, and the intensive margin, capturing the size of these receipts.

[18] Hellerstein and Ryan omit all countries with zero receipts from the estimation of the model.

stages of economic, financial, or political crises—and the related return of currency to the United States. Such lags could be long and variable, which potentially confounds attempts at analyzing demand dynamics by examining a time series consisting only of receipts data.[19] We avoid this incongruity by analyzing net shipments rather than receipts, since net shipments align better in time with developments that determine demand for U.S. currency.[20]

Our approach to panel regressions contrasts with that of Hellerstein and Ryan (2011), which model receipts along two margins: the extensive margin, capturing whether the receipts are observed or not, and the intensive margin, capturing the size of these receipts.[21] The intensive margin model is a negative binomial regression model. Their choice appears to be guided by the following considerations. Their dependent variable is always positive, which allows them to take logs of it and rely on the international trade literature estimating gravity models for econometric model guidance.[22] Recent research in that field, for example, Silva and Tenreyro (2006), argues that the OLS estimator will be inconsistent for models with non-linear transformations in the presence of heteroscedasticity and suggests a Poisson pseudo-maximum likelihood estimator instead. In turn, Hellerstein and Ryan argue that for their particular application an extension of

[19] Currency might be particularly slow to return from nations that impose controls on the importation of U.S. currency that make it difficult to replace worn notes. Recent estimates indicate that $100 bills—the most convenient stores of value—remain in circulation for an average of 15 years. More information is available at the Federal Reserve Board's website at www.federalreserve.gov/faqs/how-long-is-the-life-span-of-us-paper-money.htm.

[20] As another example, consider a country that acts as a distribution hub for receipts from or shipments to a particular geographical region. Again, gross inflows will have difficulty capturing this role.

[21] As we discuss later in the paper, we estimate a model on the global, aggregate data, in addition to regressions based on a panel of countries.

[22] A gravity model of trade in international economics, typically a non-linear equation, predicts bilateral trade flows, for example bilateral exports of a given good or a goods basket, based on the economic sizes of (often using GDP measurements) and distance between two units. Because sometimes exports are zero, Santos Silva and Tenreyro (2006) argues that estimation of the log-linearized gravity equation by OLS in presence of heteroscedasticity results in biases. The trade literature offers a few solutions to this problem, including theoretical models explicitly allowing for zero exports, empirical models accounting for unobserved heterogeneity and sample selection, or estimation techniques such as a Poisson pseudo-maximum likelihood estimator.

the Silva and Tenreyro's approach—a negative binomial model—is more suitable. In contrast, while explicitly recognizing that flows can be either positive or negative, our approach of estimating a panel model with country-specific fixed effects is not subject to Silva and Tenreyro's critique.

There are two final differences between our approach and Hellerstein and Ryan's. Our sample period is quite different: we use monthly data from 2000 through 2013, a period that includes several years beyond the collapse of Lehman Brothers in the fall of 2008; as will be seen, demand for currency in this period was quite different. In contrast, Hellerstein and Ryan's sample is annual and runs from 1990 to 2007. Finally, as for our research question, we quantify the relationship between dollar banknote flows between the United States and other countries using both country-specific and global factors.

V. Aggregate estimates of U.S. currency abroad

A. Background

As of the end of 2013, about $1.2 trillion in U.S. currency was in circulation, of which 77%, or nearly $1 trillion, was in $100 notes. Currency growth has averaged nearly 7 percent, or about 2 percentage points above GDP, since 1989; for the period since 2001, currency growth has averaged a bit less than 6 percent, but still about 2 percentage points above U.S. nominal GDP growth. Even more strikingly, since 2008, currency growth has averaged just over 7 percent per year, nearly five percentage points above U.S. nominal GDP growth. The large difference between currency growth and nominal GDP growth is largely due to international demand for U.S. currency, though domestic demand has also likely been elevated due to the extremely low interest rates in effect over this period.[23]

Notwithstanding the challenges described in Section II, Judson (2012) presents a range of estimation methods and estimates of the stock of U.S. currency abroad from the 1970s to 2011. These estimates indicate that the total share of U.S. currency in circulation abroad is now likely slightly above one-half, and that that share increased markedly in the past few years.

B. A basic aggregate regression

In our first step in quantifying the link between international demand for U.S. currency notes and economic and political developments, we estimate the relationship between net commercial bank shipments of U.S. currency overseas to all locations and various global and regional measures of risk and uncertainty. Intuitively, we expect international demand for U.S. dollars to be stronger during periods of higher political and economic uncertainty.[24]

As shown in Figure 2, total net commercial bank shipments peaked most obviously in late 1999, in late 2001, in late 2008, and most recently in March 2014, coinciding with the crisis in Argentina, century date change, the collapse of Lehman Brothers, and, most recently, the events in Ukraine.

Table 1 reports results for our set of baseline regressions using different measures of risk and global macro variables. The results shown in this table are based on non-seasonally adjusted monthly data and cover the period from January 2000 to December 2013. We start by investigating the explanatory power of the most widely used proxies for financial market

[23] Judson (2012) presents regression results indicating that total currency demand is positively correlated with GDP growth and measures of U.S. dollar flows abroad, and negatively correlated with interest rates. Analysis of the link between very low interest rates and currency demand for the U.S. and other countries is underway.

[24] The International Currency Awareness Program's interviews found that economic and political uncertainty were the most commonly mentioned factors driving international dollar usage.

volatility in developed markets and sovereign default risk in developing countries. Specifically, we consider the Chicago Board Options Exchange Market Volatility Index, or VIX, a measure of short-term expectation of the U.S. stock market volatility, as a measure of risk in the developed world, and the J.P. Morgan Global Sovereign Spread index, or EMBI, as a proxy for sovereign default risk of developing countries. As shown in column 1 of table 1, the explanatory power of the regression, summarized by the adjusted R^2, at six percent, is quite low. Furthermore, our robustness analysis indicates that this result is driven by the two observations corresponding to the outbreak of the financial crisis, September and October 2008. When we exclude these two observations from the sample, both the VIX and the EMBI lose their statistical significance. The lack of explanatory power of these standard measures of volatility motivates us to explore alternative measures of uncertainty. Specifically, we evaluate alternative sources of risk related to the real side of the economy such as the uncertainty indexes (EPU) for the United States and Europe compiled by Baker, Bloom, and Davis (2013) which are intended to capture policy-related economic uncertainty.[25] As shown in column 2, these indexes prove to be helpful predictors of U.S. currency flows and improve significantly the fit of our regression. In particular, our results suggest that periods of higher economic uncertainty in the developed world are associated with higher demand for U.S. banknotes abroad. Strong currency growth during the last financial crisis of 2008 and the subsequent European debt crisis in 2011 support these findings.

[25] The U.S. economic policy uncertainty index is constructed from three components: search results for references to economic uncertainty and related terms appearing in articles published by major newspapers, a dollar-weighted sum of the number of upcoming federal tax code expirations, and disagreement among economic forecasters as indicated by dispersions of economic forecasts. The construction of the European index is similar to that of the U.S. version but does not include a component reflecting upcoming tax code expirations. For this index, dispersion is measured with respect to forecasts made for the economies of Britain, France, Germany, Italy, and Spain.

The last financial crisis provided evidence of stronger co-movements among developed markets; for example, episodes centered in the United States were immediately discounted in European asset prices, and vice versa. To control for these correlations and to disentangle the effects of global economic and market uncertainty on currency demand, we use principal component analysis. We extract factors from four inputs: month-average values of the VIX and VSTOXX indices, and the monthly U.S. and European economic policy uncertainty indices. These series were chosen as proxy measures of market stress and economic policy uncertainty in the U.S. and developed Europe. The first principal component (PC), market stress and policy uncertainty, replicates the shared variance of the four inputs; the second component (policy uncertainty vs. market stress), tracks differences between co-movements of the economic policy uncertainty indices and co-movements of the two market stress proxies, and thus can be used to distinguish between the impact on currency demand of changes in economic policy uncertainty relative to market stress. Analogously, the third PC (U.S. vs. European) can be used to distinguish between the impact of changes in U.S. factors relative to changes in European factors. [26] As shown in column 3, the three principal components prove to be helpful in explaining currency flows. The positive and statistically significant estimate of the first (PC) suggests that higher economic and market-related uncertainty in the United States and Europe is related to stronger currency flows. The second PC points to a greater sensitivity of international currency flows to changes in economic policy uncertainty factors relative to changes in market stress in the US and Europe. Similarly, estimates for the third PC indicate that changes in US economic uncertainty and market stress will have a greater impact on international demand for

[26] Appendix A provides a detailed explanation of these factors.

U.S. currency than changes in European uncertainty factors, in other words, currency flows appear to be more sensitive to US events than to European developments.

Building on these results, in columns 4 we expand our set of covariates and include a group of widely used global macro factors that have been previously identified by market analysts as potential drivers of demand for U.S. banknotes. In doing so, we evaluate the performance of global GDP growth, global inflation, the broad U.S. dollar index, oil, and gold prices. Whereas estimates for the principal components remain positive and statistically significant, we find no explanatory power in the set of global macroeconomic indicators.

As noted above, and as illustrated in Figures 3 and 4, we conjecture that the factors driving international demand for U.S. currency might have changed in 2008. Figure 3 displays cumulative net payments of currency (both domestic and international) over the course of the year for recent years. The red line, 2008, tracks the gray line, the average of 2003-2007, until mid-September, at which point it turns up sharply. Subsequent years show elevated patterns much more similar to the latter part of 2008 than to the years prior to 2008. Figure 4 shows annual commercial shipments of currency for three different periods (1994-2000, 2001-2008:Q3, and 2008:Q4-2013) and for two sets of countries, Russia and Argentina (the red bars) and all other countries (the gray bars). In the most recent period, shipments to Russia and Argentina were higher, but, more remarkably, shipments to all other countries swung from being negative on net to being strongly positive and significantly larger than the shipments to Argentina and Russia.

Based on these simple observations about aggregate shipment patterns beginning in late 2008, we investigate further the role of global uncertainty and macro factors by evaluating their explanatory power in the pre and post-crisis period. Interestingly, we find strong evidence which suggest that global factors have become important drivers of international currency demand since the most recent financial crisis.

In table 2, we begin with the same regression as in the final column of table 1. In the second column, we split the sample into two periods, the "pre-crisis" period—prior to September 2008—and the "crisis" period, beginning in 2008 and running through the end of the sample. The market stress and policy uncertainty PC, our proxy for global economic and market uncertainty, proves to be economically and statistically significant throughout the different regression specifications during the crisis period starting in the fourth quarter of 2008. The second PC points in the same direction, with coefficients being positive and statistically significant during the crisis period. Furthermore, whereas the full sample results provide no evidence of the value of global macroeconomic factors as predictors of currency demand, we find that global factors' estimates such as the broad U.S. dollar index, oil price, and global inflation are statistically and economically significant during the crisis period. Conversely, global GDP growth appears to be a helpful predictor of currency flows during the pre-crisis period. The negative coefficient indicates that periods of global economic growth are associated with a decrease in total net shipments of U.S. currency notes.

Overall, our aggregate regression analysis provides novel insights into the study of U.S. currency flows. In particular, our results suggest that, over the recent years, global uncertainty and macroeconomic factors have become increasingly important determinants of international demand for U.S. currency.[27]

[27] Results are robust to the exclusion of U.S. dollar flows to Argentina and Russia from total net shipments as well as robust to the exclusion of observations for September and October of 2008.

VI. Panel regressions

A. Introduction: coverage for this panel relative to total shipments

Our next step is to examine the relationship between currency shipments and local and global factors at the country level. As noted earlier, the commercial bank shipments dataset contains data for nearly every country in the world. However, as a practical matter, we focus on a subset of about sixty countries for which shipments over time have been non-negligible. Of that set of countries, we were able to obtain quarterly or monthly data on income growth, inflation, exchange rate movements, and equity market volatility for nearly fifty countries.[28]

B. All countries

In this section, we build on our aggregate regression analysis and consider a large panel consisting of 6,861 monthly observations from January 2000 through December 2013 for a group of 44 developed and developing countries. Using a panel data approach results in more precise estimates than the analogous individual time-series regressions. Furthermore, even in the case where the regression coefficients differ across countries, the pooled estimator provides information about the average regression coefficient.

In these regressions, we use as our dependent variable the ratio of net shipments to GDP in order to make the units comparable across countries. Based on specification testing, we use fixed effects: Hausman test results are mixed depending on the subset of countries chosen, and fixed effects will yield consistent, though not necessarily efficient results. Based on the results of the aggregate regressions, we move directly to a specification with separate coefficients for

[28] While we acknowledge the potential importance of sample selection, we do not include a sample selection correction into our models for two reasons. First, our dependent variable, net shipments / GDP, can be either positive or negative, a condition that is not amenable to sample selection correction. Second, we include fixed effects, which should mitigate sample selection problems.

the pre-crisis and crisis periods.[29] We evaluate the explanatory power of both global and country-specific financial and economic factors using the following fixed effects specification:

$$NET_{i,t} = const_{i} + \beta_{UNC}\, UNC_{t} + \beta_{GINFL} \log(GINFL) + \beta_{GDP}\, GDP_{t} + \\ \beta_{FX}\, FX_{t} + \beta_{INFL} \log(INFL_{i,t}) + \beta_{RISK}\, RISK_{i,t} + crisis^{t} + error_{i,t},$$

Our set of regressors includes the same global variables as in the aggregate regressions reported in Table 2: the principal components uncertainty factors (UNC), global inflation (GINFL), the broad U.S. dollar index (FX), and global GDP growth (GDP). In addition, we include country-specific variables that experience suggests might be correlated with dollar flows: financial market risk (RISK) and local inflation (INFL). Our financial market risk measure is realized equity market volatility and is constructed as the monthly variance of the daily growth rates of the local equity index. Intuitively, we would expect that higher uncertainty in local financial markets will be associated with higher demand for US currency. We also include local inflation as a regressor because inflationary episodes have often been associated with increased dollar usage.

B. Country groups

In addition to our observations about the break in the time series in September 2008, country-level shipment patterns and the knowledge gathered through the International Currency Awareness Program suggest that the relationship between currency shipments and global and macro variables might be different for different countries. We identify several groups of countries. Specifically, we consider individual panels for emerging and developed countries,

[29] The pre-crisis period covers the beginning of our sample period through the second quarter of 2008. The post-crisis period starts in the third quarter of 2008 and ends in the fourth quarter of 2013.

countries of the Former Soviet Union, net exporters and importers of U.S. banknotes, in-transit markets, and largest market players.[30]

Regression results by country group are reported in Tables 3A and 3B, with the full panel in column 1. These results for the full panel are broadly similar to the aggregate results and in line with our expectations, though there are a few exceptions. As in the aggregate regressions, the measures of global uncertainty are positive and at least marginally statistically significant for all three factors during the crisis period, but are statistically insignificant or negative in the pre-crisis period. As in the aggregate regressions, global GDP growth is negative and statistically significant before the crisis but not during the crisis period. Broad dollar appreciation is negative and statistically significant in both periods. We are not sure what to make of this result: the findings of the ICAP project and ongoing market and dealer commentary indicate that some dollar users arbitrage and prefer to buy dollars when they are relatively cheap. This relationship is a question for further research. All four country-specific coefficients—for equity market volatility and for inflation, are positive and statistically significant for both periods in the full panel.[31] After accounting for the country (fixed) effects, though, relatively little of the variation in the data for the full panel is explained: the R^2 is 3 percent. This result is not very surprising: this regression combines countries whose experiences with, and uses of, dollars are quite disparate.

The next regressions examine these relationships for groups of countries that we expect to be more similar, either because of their level of development, their role in the distribution system for dollars, or their position as a net importer or exporter of dollars. The second column

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[30] See Appendix C for lists of the countries in each group.

[31] The differences between the coefficient estimates in the two periods are statistically significant at the 10% level.

reports regressions estimated just for emerging market economies (EME). For these countries, only the isolated uncertainty component is statistically significant, and only in the crisis period. The relationship between global macro variables and dollar shipments to EMEs is a bit weaker in the pre-crisis period and somewhat counterintuitive in the crisis period: for this period, global inflation is negatively correlated with EME currency shipments and global GDP growth is positively correlated. As for the full panel, the coefficients for equity market volatility and inflation are positive and statistically significant in both periods. Notably, the R^2 for this group of countries is considerably higher, at 26 percent.

The third column reports results of a panel regression with only Russia, Ukraine, and Kazakhstan, the three countries of the former Soviet Union for which shipments have been significant and for which macroeconomic data were available. These countries, especially Russia, have accounted for a very significant portion of the commercial shipments in our dataset over the full sample and have had similar—though certainly not identical—experiences with economic and political instability and developing financial markets and infrastructure. Most notably, inflation is statistically significant and positive prior to the crisis and uncertainty is statistically significant during the crisis period. It should be noted that for these countries, the crisis period was a period of relative calm domestically.

The fourth column reports results for a group of countries that appear to function largely as distribution centers for currency. For these countries, there is little evidence of domestic use of dollars and, at the same time, they are home to large banknote retailers and major international airports. Information gathered during the ICAP project indicated that most of the dollars shipped to or from these countries had come from third countries. Coefficients on global inflation and measures of stress are generally significant and positive for these countries, and the R^2 is nearly as high as it is for the former Soviet Union, at 12 percent.

The final column of Table 3A reports results for industrialized countries. In general, dollar usage in these countries appears to be minimal and limited to trade and tourism. Not surprisingly, coefficient estimates are generally small in magnitude, relatively few are statistically significant, and the R^2 is quite low.

Table 3B groups countries slightly differently, by shipment patterns. The first column shows the full sample, as in Table 3A. The following columns group the countries in countries that have shown large shipments relative to GDP and also overall ("Big"), countries whose shipments are positive overall ("NetPos"), countries whose shipments are both large and positive ("BigPos"), and the same for negative net shipments ("NetNeg" and "BigNeg"). In these results, local equity market volatility is consistently positive and statistically significant in the pre-crisis period but less so in the crisis period. Local inflation is nearly always statistically significant and positive in both periods. Measures of stress are more strongly and consistently positive and statistically significant during the crisis period.

Figure 5 summarizes the relative contributions of local variables—the red bars—and global variables—the blue bars—over the pre-crisis and crisis periods for each of the regression samples in Tables 3A and 3B. Over the full sample, the first row, the contributions of global factors were negative prior to the crisis but positive during the crisis; local variables appeared to have about the same significance overall. Across the country groups, the contribution of global factors often changed sign and increased in magnitude, especially in the country groups where dollar usage is substantial—the former Soviet Union and countries with large and net positive shipments.

C. Filtered Variables

Given the volatile nature of the shipments data, we conduct an additional exercise based on the work of Forbes and Warnock (2012) on capital flow surges, in which they define periods of surges and stops in capital.[32] Our approach is in the same spirit, but uses band pass filtering to obtain low-frequency components of shipments. These low-frequency components comprise long-run trends in the shipments data along with aperiodic fluctuations that are analogous to the surges and stops identified by Forbes and Warnock (2012).

We filtered net currency shipments with the band pass filter developed by Christiano and Fitzgerald (2003, the CF filter).[33] We estimated high-frequency components corresponding to periods up to 12 months and low-frequency components corresponding to periods no less than 12 months. Seasonal fluctuations therefore were included in the high-frequency component along with transitory fluctuations. An examination of the data indicates that seasonal fluctuations are negligible for most cross-sections, and the high-frequency components therefore primarily reflect transitory fluctuations.[34]

[32] Banknote flows, are, after all, the physical component of financial capital flows.

[33] Band pass filtering is a technique used to extract frequency components from a time series by applying weights derived in the frequency domain. The spectral representation theorem provides an ideal set of weights for this purpose, but these weights are applicable only to a hypothetical data set of infinite length. Since actual datasets are finite, it is necessary to use a band pass filter comprising weights which approximate the ideal. CF filter weights minimize squared differences from the ideal weights premised on an assumption that the time series to be filtered is a random walk.

The CF filter is "asymmetric", meaning that the weights applied to observations at times t+q and t-q in the estimation of the filtered component at time t are not necessarily the same. We chose this filter because it allowed us to estimate frequency components for our entire data set, whereas the use of a symmetric filter would have resulted in a meaningful loss of data through truncation. Indeed, we had difficulties applying the Forbes and Warnock (2012) methodology directly because of this limitation.

[34]The use of asymmetric weights produces phase shifts in the filtered components which can cause fluctuations that are unsynchronized with fluctuations in the raw data. We looked for evidence of significant phase shifts by calculating cross correlations between the raw data and the low-frequency components at leads and lags of up to 36 months. If filtering had resulted in significant shifts, the misalignment of fluctuations would have resulted in higher correlation of the raw data to leads or lags of the low-frequency components than to the contemporaneous components. For each cross-section in our data set, the raw data were more highly correlated to the

The results of regressions using low-frequency net shipments as a share of GDP are reported in Tables 4A and 4B and summarized in Figure 6; the results are broadly similar to those with unfiltered shipments.

[To be extended]

VII. Implications of currency demand from abroad for reserves draining and the Federal Reserve's exit strategy

From the domestic perspective, understanding the factors driving international dollar usage has important implications for a wide range of Federal Reserve operational considerations and exit strategies from the quantitative easing programs, including daily open market operations and potential large-scale liquidity draining operations, the management of the Federal Reserve's portfolio, analysis and forecasting of the Federal Reserve's income, the interpretation of currency figures as part of monetary analysis, and others. In particular, the higher the currency growth, the more reserve balances get drained by this autonomous factor, and, hence, the less reserve balances should be drained by the Federal Reserve to normalize its balance sheet. In addition, in the process, the Federal Reserve will spend less on remuneration of reserve balances, and, hence, will remit more to the U.S. Treasury.

Currency growth decelerated from 8.6% in 2012 to 6.3% in 2013. This deceleration coincided with decreases in the average value of the European uncertainty index (from 186 in 2012 to 141 in 2013) and the U.S. uncertainty index decreased (from 168 to 122). Based on the empirical presented earlier, currency growth may decelerate further over the next few years if uncertainty in Europe and the U.S. continues to abate.

contemporaneous low-frequency components than to components at any lead or lag, which suggests that phase shifts were negligible.

The ongoing deceleration of currency growth has important implications for the exit strategy through which the FOMC will normalize the conduct of monetary policy over the next several years. The key elements of this strategy are monetary policy measures through which the Federal Reserve will normalize the size of its balance sheet and reduce reserves to the smallest levels that are consistent with the implementation of monetary policy. Currency growth drains reserves, and the rate at which currency grows therefore will be one of the parameters that determine the amount of time needed to complete the exit and the sizes of reserves-draining operations involved.

Greenlaw, Hamilton, Hooper and Mishkin (2013) used the exit strategy principles articulated in the minutes of the FOMC's June 2011 meeting, along with assumptions about future interest rates and currency growth, to project the impact of the strategy's implementation on future reserves levels and remittances of earnings by the Federal Reserve to the Treasury. We use their assumptions to illustrate how slower currency growth would impact exit strategy outcomes.

To make their projections, Greenlaw, et al. assume currency will grow at an annual rate of 7 percent through 2020, by which time they expect the exit to be completed. Coincidentally, this is the average growth rate for 2008 – 2013, when U.S. and European policy uncertainty was elevated relative to what it was prior to the 2008 financial crisis. Currency grew at slower rates averaging annual rate of 4 percent during 2000 – 2007, when uncertainty in the U.S. and Europe was lower. Future currency growth rates might be closer to this average if uncertainty continues to diminish.

Table 5 shows the implication of a reduction in the annual currency growth from the assumed rate of 7 percent to the 4 percent average for the pre-crisis period. Differences between the two growth trajectories equate to differences in projected reserve balances at future year-end dates. Thus, 4 percent growth through 2020 reduces projected year-end Federal Reserve notes by $353 billion relative to 7 percent growth, which implies $353 billion more in reserve balances the Federal Reserve would have to drain through SOMA sales or temporary operations to achieve a targeted level of reserves by the end of that year.

The three columns to the right show the estimated impact on Treasury remittances of currency growth at the 4 and 7 percent rates. Currency growth increases Treasury remittances by reducing reserve balances on which the Federal Reserve pays interest (IOR), thereby reducing Federal Reserve Bank expenses and increasing earnings available to be paid to the Treasury. The current IOR rate is 25 basis points, which is at the top of the FOMC's target federal funds rate of 0 – 25 basis points. To estimate the impact on future remittances, Blue Chip forecast federal funds rates were multiplied by the projected year-end currency levels.

Table 5
Federal Reserve Note Outcomes Based on Two Currency Growth Paths
Billions of dollars except as noted

	Projected Year-End Federal Reserve Notes			Projected Federal Funds Rate	Projected Impact on Federal Reserve Remittances to the Treasury		
Year	(1) 4% Growth Rate	(2) 7% Growth Rate	Difference (2) - (1)		(3) 4% Growth Rate	(4) 7% Growth Rate	Difference (3) – (4)
2014	1,232	1,269	37	0.30%	4	4	0
2015	1,284	1,361	77	1.00%	13	14	-1
2016	1,338	1,460	122	2.25%	30	33	-3
2017	1,394	1,566	172	3.50%	49	55	-6
2018	1,452	1,679	226	3.75%	54	63	-8
2019	1,513	1,800	287	4.00%	61	72	-11
2020	1,576	1,929	353	4.00%	63	77	-14
Total, 2014 – 2020					**273**	**317**	**-44**

Currency growth at an average annual rate of 7 percent through 2020 would reduce cumulative IOR expenses from 2014 to 2020 by an estimated $317 billion, while growth at an annual rate of 4 percent would reduce expenses by only $273 billion. The difference between these amounts implies a $44 billion cumulative reduction in Treasury remittances if currency grows at 4 percent rather than 7 percent. Annual differences in estimated remittances increase from less than $1 billion in 2014 to $14 billion in 2020.

Based on their assumptions and interpretation of the FOMC's exit strategy, Greenlaw, et. al expect annual remittances to the Treasury to peak at $105 billion in 2014. Thereafter, they expect remittances to decrease to a low of $33 billion in 2018 and 2019 due to reductions to the SOMA and higher IOR expenses. Currency growth at a 4 percent annual rate would reduce these projected remittances to $25 billion in 2018 and $22 billion in 2019 and increase the probability that the Federal Reserve would suspend remittances to the Treasury during the later stages of the exit.

VIII. Conclusions and future work

In sum, across a span of 14 years and a few dozen countries, we find that both global local factors are correlated with shipments of U.S. dollars abroad. In the aggregate, where only global factors are relevant, we find that net shipments of dollars from the United States to other countries are very strongly correlated with various measures of uncertainty in the period since 2008 and considerably less so in earlier years.

We view this work as a first step toward further understanding of demand for U.S. banknotes worldwide and implications of those forces for U.S. monetary policy implementation and, possibly, the countries where dollars are used. We see many potential avenues for further exploration, including the following. First, what is the relationship between dollar flows and capital flows in other forms? Second, what might more granular disaggregation (say, to the country level) tell us?

[To be extended]

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APPENDIX A: CURRENCY DATA SOURCES AND DEFINITIONS

Several agencies and publications carry data on U.S. currency in circulation, and several additional sources are available internally in the Federal Reserve. The publications and the level of detail provided by each source are summarized in the table. None of these sources provides any information about domestic and international movements of U.S. currency.

Public data sources on U.S. currency in circulation						
Publication name	**Source**	**URL**	**Frequency**	**Date Range**	**Definition**	**By denom-ination?**
H.4.1	Federal Reserve	http://www.federalreserve.gov/releases/h41/	Weekly average and Wednesday	1914; Time series data online starting in December 2002.	Table 1: Currency in circulation Tables 9 and 10: Federal Reserve notes, net	No
H.6	Federal Reserve	http://www.federalreserve.gov/releases/h6/	Weekly average	1989-present	Currency component of the money stock	No
Treasury Bulletin	Treasury	http://www.fms.treas.gov/bulletin/index.html	Quarter-end	Current year	All types of currency outstanding, held by the Treasury and Federal Reserve, and in circulation.	Yes
Annual Report	Federal Reserve	http://www.federalreserve.gov/boarddocsfs/rptcongress/default.htm#ar	Annual. Data are reported for month-end and month average for previous year and year-end and year average for earlier years.	1914-present		No
Z.1 (Flow of Funds)	Federal Reserve	http://www.federalreserve.gov/releases/z1/	Quarter-end	1996-present	Currency in circulation	

Public data sources on U.S. currency in circulation						
Publication name	**Source**	**URL**	**Frequency**	**Date Range**	**Definition**	**By denom-ination?**
Banking and Monetary Statistics and **Annual Statistical Supplement (various years)**	Federal Reserve	http://fraser.stlouisfed.org/	Weekly average and Wednesday; monthly average and month-end; Annual average and year-end	1914-1990	Currency in circulation	Yes, for selected dates.
Online	Federal Reserve	http://www.federalreserve.gov/ paymentsystems/coin_data.htm	Annual, year-end	1990-present	Paper currency (Federal Reserve notes, U.S. notes, and currency no longer issued)	Yes
Statistics on payment, clearing and settlement systems in the CPSS countries	Bank for International Settlements	http://www.bis.org/ publ/cpss99.htm http://www.bis.org/ publ/cpss99.pdf	Annual, year-end		Notes and coin "issued" (held outside the monetary authority)	Yes

Notes

Currency in circulation includes Federal Reserve notes, Treasury notes, no longer issued notes, and coin held outside the Federal Reserve and Treasury.

Federal Reserve notes, net includes Federal Reserve notes outstanding less Federal Reserve notes held at the Federal Reserve.

The currency component of the money stock includes currency (including coin) outside the U.S. Treasury, Federal Reserve Banks, and the vaults of depository institutions.

APPENDIX B. PRINCIPAL COMPONENTS ANALYSIS

Principal components analysis (PCA) is statistical technique used to transform the variance structure of a standardized set of correlated, observed variables into an identical number of linearly uncorrelated latent variables.[35] We extracted principal components from four inputs: month-average values of the VIX and VSTOXX indices,[36] and the monthly U.S. and European economic policy uncertainty indices discussed in the text. These series were chosen as proxy measures of market stress and economic policy uncertainty in the U.S. and developed Europe. They have been highly correlated to one another since the beginning of 2000, although the two proxies for market stress have been less highly correlated to the two policy uncertainty indices than they were earlier since the 2008 financial crisis.

Principal component scores are computed by summing the products of factor loadings and standardized versions of the PCA inputs. A positive factor loading indicates positive correlation between principal component scores and an input, and a loading that is larger in magnitude indicates stronger correlation than a loading with a smaller magnitude. The matrix below lists the loadings produced by our PCA analysis.

Table B.1: Principal Components Loading Matrix

	Factor Descriptor			
	Market Stress and Policy Uncertainty	Market Stress vs. Policy Uncertainty	U.S. vs. European Stress / Uncertainty	Residual Variance
VIX Index	0.50	-0.53	0.20	0.66
VSTOXX Index	0.52	-0.44	-0.34	-0.65
U.S. economic policy uncertainty	0.51	0.44	0.70	-0.25
European economic policy uncertainty	0.47	0.58	-0.60	0.30

[35] For an explanation of principal components analysis (PCA), see Schlens (2003).

[36] The VSTOXX index is similar to the VIX, but is calculated using European option prices rather than U.S. option prices. Specifically, it is derived from the implied volatility of 1-month options on the STOXX index of 50 large-cap European equities. In this analysis, we use the VIX as a proxy for market stress in the U.S. and the VSTOXX as a proxy for market stress in developed Europe.

All loadings for the first principal component (market stress and policy uncertainty) are positive, and the variation of this principal component therefore captures variation that is comment to all four inputs. Loadings for the second principal component (policy uncertainty vs. market stress) indicate that it tracks differences between co-movements of the economic policy uncertainty indices and co-movements of the two market stress proxies based on variation that is not captured by the first principal component, and thus can be used to distinguish between the impact on currency demand of changes in economic policy uncertainty relative to market stress. Analogously, the third factor (U.S. vs. European stress / uncertainty) can be used to distinguish between the impact of changes in the U.S. relative to changes in Europe based on variation that is not captured by the first two principal components. Scores for the fourth principal component simply capture residual variance that is not captured by the first three.

Appendix C: Country Panels	
FSU	KAZ RUS UKR
Big	RUS TUR UKR CHN MEX KAZ EGY KOR THA ARG
EME	BRA CHL CHN EGY MEX PHL THA TUR TWN
Hub	AUT CHE DEU GRB HKG SGP
Industrialized	AUS AUT BEL CAN DNK ESP FIN FRA GRC IRL ISL ITA JPN KOR LUX NLD NOR NZL PRT SWE
NetNeg	CHN HKG KOR MEX PAN PHL POL SGP THA TUR
NetPos	ARG AUS AUT BEL BRA CAN CHE CHL DZE DEU DNK EGY ESP EST EUR FIN FRA GBR GRC HUN IRL ISL ISR ITA JPN KAZ KHM LUX NLD NOR NZL PRT RUS SLV SVK SVN SWE TWN UKR

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Table 1: Aggregate Regressions
Dependent variable: NSA Total net shipments
Sign flipped on PC US vs Europe
Dependent variable: NSA Total net shipments
Monthly, including Sep-Oct. 2008

	EMBI+VIX		Uncert only		Uncert PCA4		Add'l Vars	
EMBI (Total)	-2.7^{*}	(-2.0)						
VIX	118.7^{*}	(2.6)						
US policy uncert.			25.1^{*}	(2.5)				
EU policy uncert.			29.0^{*}	(2.4)				
PC: Uncert and stress					886.2^{*}	(5.0)	761.2^{*}	(4.9)
PC: Uncert vs stress					1196.6^{*}	(4.6)	1119.1^{*}	(4.6)
PC: US vs Europe					964.2^{*}	(2.1)	1158.2^{*}	(2.4)
Global GDP growth							-174.2	(-1.4)
Global inflation							337.0	(1.5)
Broad dollar apprec.							-58.3	(-0.2)
Oil price growth							-39.0	(-1.4)
Gold price growth							77.7	(1.1)
Constant	-430.0	(-0.6)	-5295.5^{*}	(-8.7)	917.6^{*}	(4.8)	0.5	(0.0)
Observations	168		168		168		159	
R^2	0.07		0.39		0.39		0.43	
Adjusted R^2	0.06		0.38		0.37		0.40	

t statistics in parentheses
Shipments are in billions of dollars.
$^{+}$ $p < 0.10$, * $p < 0.05$

Table 2: Aggregate Regressions
Dependent variable: NSA Total net shipments. Monthly including Sep-Oct 2008.
Separate coefficient estimates for periods up to 2008:Q3 and after 2008:Q3

	1 Period		PCA4		PCA4+Macro		Ref-PCA4		Ref2-PCA4	
PC: Uncert and stress	761.2*	(4.9)								
PC: Uncert and stress, pre-crisis			194.9	(1.3)	−119.7	(−0.7)	−157.5	(−1.1)		
PC: Uncert and stress, crisis			936.9*	(3.0)	924.7*	(2.4)	1053.4*	(2.8)	777.4*	(2.3)
PC: Uncert vs stress	1119.1*	(4.6)								
PC: Uncert vs stress, pre-crisis			95.6	(0.3)	−201.6	(−0.6)	−163.9	(−0.6)		
PC: Uncert vs stress, crisis			825.3*	(2.1)	813.2*	(2.5)	615.5	(1.6)	573.4	(1.4)
PC: US vs Europe	1158.2*	(2.4)								
PC: US vs Europe, pre-crisis			122.1	(0.2)	475.0	(0.8)				
PC: US vs Europe, crisis			−246.9	(−0.4)	198.4	(0.3)				
Global GDP growth	−174.2	(−1.4)								
Global GDP growth, pre-crisis					−693.7*	(−3.4)	−689.4*	(−3.5)	−569.1*	(−3.8)
Global GDP growth, crisis					−168.5	(−0.8)	−105.9	(−0.5)		
Global inflation	337.0	(1.5)								
Global inflation, pre-crisis					−195.0	(−0.8)	−149.4	(−0.6)		
Global inflation, crisis					1514.7*	(2.8)	1607.1*	(3.0)	1180.7*	(2.7)
Broad dollar apprec.	−58.3	(−0.2)								
Broad dollar apprec., pre-crisis					−310.4	(−1.5)	−382.0*	(−2.2)	−375.6*	(−2.2)
Broad dollar apprec., crisis					−787.7+	(−1.7)	−623.0	(−1.5)		
Gold price growth	77.7	(1.1)								
Gold price growth, pre-crisis					55.4	(0.9)				
Gold price growth, crisis					67.7	(0.7)				
Oil price growth	−39.0	(−1.4)								
Oil price growth, pre-crisis					−14.0	(−0.6)				
Oil price growth, crisis					−96.3+	(−1.8)				
Crisis (dummy)			2434.3*	(3.5)	−6090.6*	(−3.0)	−6315.0*	(−3.2)	−3748.9*	(−2.6)
Constant	0.5	(0.0)	−483.2	(−1.6)	2642.3+	(1.9)	2410.3+	(1.9)	1512.5*	(2.5)
Observations	159		168		159		159		159	
R^2	0.43		0.49		0.61		0.59		0.56	
Adjusted R^2	0.40		0.46		0.56		0.56		0.55	

t statistics in parentheses

Shipments are in billions of dollars.

$^+$ $p < 0.10$, * $p < 0.05$

Table 3A: FE Split-Sample Country-Level Panel Regressions by Region
Includes 2008:9 and 2008:10.
FE. Dependent variable: Net shipments /GDP

	All countries	EME	FSU	Hub	Indust
Equity mkt vol, pre-crisis	23.9*	18.4*	8.7	6.0	2.4
	(8.3)	(6.3)	(0.9)	(0.3)	(0.8)
Equity mkt vol, crisis	10.1*	14.2*	−39.1*	−22.3	4.9+
	(2.9)	(3.4)	(−2.7)	(−1.4)	(1.7)
Inflation, pre-crisis	8.6*	15.0*	31.0*	−100.5*	13.2*
	(5.3)	(13.0)	(2.9)	(−4.3)	(2.4)
Inflation, crisis	27.0*	46.5*	−3.0	−121.9*	−10.5+
	(6.6)	(11.1)	(−0.1)	(−4.0)	(−1.7)
PC: Uncert and stress, pre-crisis	−18.9*	9.6	−76.6	−43.0	3.4
	(−2.3)	(1.0)	(−1.5)	(−1.2)	(0.6)
PC: Uncert and stress, crisis	30.6*	−4.4	258.0*	136.3*	10.3
	(2.6)	(−0.3)	(3.3)	(2.9)	(1.2)
PC: Uncert vs stress, pre-crisis	19.5	−6.0	38.2	252.0*	2.2
	(1.3)	(−0.3)	(0.4)	(4.2)	(0.2)
PC: Uncert vs stress, crisis	40.0*	41.9*	−14.1	103.7*	30.9*
	(3.2)	(2.9)	(−0.1)	(2.1)	(3.4)
PC: US vs Europe, pre-crisis	18.2	−1.5	57.7	−125.7	28.2
	(0.6)	(−0.0)	(0.3)	(−1.1)	(1.3)
PC: US vs Europe, crisis	38.2+	22.1	221.3	250.1*	18.0
	(1.7)	(0.8)	(1.3)	(2.8)	(1.1)
Global inflation, pre-crisis	−21.2+	−2.9	−234.5*	87.0+	−21.4*
	(−2.0)	(−0.2)	(−2.8)	(1.8)	(−2.6)
Global inflation, crisis	20.6	−67.3*	343.5*	361.4*	20.6+
	(1.4)	(−3.7)	(3.3)	(5.5)	(1.7)
Global GDP growth, pre-crisis	−47.5*	−20.7*	9.1	−69.1*	−4.9
	(−5.8)	(−2.2)	(0.2)	(−2.2)	(−0.8)
Global GDP growth, crisis	−7.6	18.0*	−54.8	−63.5*	−8.0
	(−1.1)	(2.2)	(−1.2)	(−2.3)	(−1.6)
Broad dollar apprec., pre-crisis	−29.2*	4.2	−5.1	−108.7*	−25.9*
	(−3.8)	(0.5)	(−0.1)	(−3.7)	(−4.8)
Broad dollar apprec., crisis	−27.4*	−33.6*	27.3	−100.2*	−24.3*
	(−2.9)	(−3.0)	(0.4)	(−2.7)	(−3.6)
Crisis (dummy)	−380.2*	49.3	−1516.0*	−1098.2*	−167.5*
	(−5.2)	(0.6)	(−3.0)	(−3.7)	(−3.2)
Constant	161.7*	−442.8*	1490.9*	−320.7	119.7*
	(2.8)	(−6.6)	(3.8)	(−1.4)	(2.9)
Observations	6861	1418	463	953	3125
NCoun	44.00	9.00	3.00	6.00	20.00
R^2	0.03	0.26	0.15	0.12	0.02
AReg R^2	0.57	0.60	0.44	0.58	0.06
Wald_p(Pre-cris = Cris)	0.00	0.00	0.00	0.00	0.01

t statistics in parentheses
Notes here as needed.
$^{+}$ $p < 0.10$, * $p < 0.05$

Table 3B: FE Split-Sample Country-Level Panel Regressions by Shipment Group
Includes 2008:9 and 2008:10.
FE. Dependent variable: Net shipments /GDP

	All countries	Big	NetPos	BigPos	NetNeg	BigNeg
Equity mkt vol, pre-crisis	23.9*	14.1*	26.9*	10.2+	16.6*	18.0*
	(8.3)	(4.2)	(7.4)	(1.9)	(3.6)	(5.4)
Equity mkt vol, crisis	10.1*	3.3	7.4+	−11.7	13.9*	16.0*
	(2.9)	(0.7)	(1.7)	(−1.6)	(2.4)	(3.2)
Inflation, pre-crisis	8.6*	15.5*	3.4	9.3*	12.3*	15.9*
	(5.3)	(9.0)	(1.2)	(2.0)	(6.8)	(12.0)
Inflation, crisis	27.0*	37.7*	19.6*	33.0*	54.8*	47.9*
	(6.6)	(7.7)	(3.7)	(4.1)	(8.2)	(9.1)
PC: Uncert and stress, pre-crisis	−18.9*	−12.2	−26.9*	−36.8+	3.4	17.3
	(−2.3)	(−1.0)	(−2.7)	(−1.8)	(0.3)	(1.5)
PC: Uncert and stress, crisis	30.6*	44.3*	39.6*	88.1*	4.8	−3.3
	(2.6)	(2.4)	(2.8)	(2.9)	(0.2)	(−0.2)
PC: Uncert vs stress, pre-crisis	19.5	4.4	20.9	7.8	17.0	−3.0
	(1.3)	(0.2)	(1.1)	(0.2)	(0.7)	(−0.1)
PC: Uncert vs stress, crisis	40.0*	61.9*	36.3*	51.1	44.4*	50.3*
	(3.2)	(3.1)	(2.4)	(1.5)	(2.1)	(2.7)
PC: US vs Europe, pre-crisis	18.2	12.7	33.0	40.8	−23.0	−15.6
	(0.6)	(0.3)	(0.9)	(0.5)	(−0.5)	(−0.4)
PC: US vs Europe, crisis	38.2+	29.4	31.7	48.8	68.9+	28.7
	(1.7)	(0.8)	(1.1)	(0.8)	(1.8)	(0.8)
Global inflation, pre-crisis	−21.2+	−31.8+	−19.7	−47.9+	−10.7	−2.7
	(−2.0)	(−1.9)	(−1.5)	(−1.7)	(−0.6)	(−0.2)
Global inflation, crisis	20.6	6.6	33.9+	92.6*	−26.3	−81.8*
	(1.4)	(0.3)	(1.8)	(2.4)	(−1.0)	(−3.6)
Global GDP growth, pre-crisis	−47.5*	−5.2	−41.8*	13.3	−61.1*	−24.1*
	(−5.8)	(−0.4)	(−4.2)	(0.6)	(−4.5)	(−2.0)
Global GDP growth, crisis	−7.6	5.6	−8.1	−11.7	−7.2	21.0*
	(−1.1)	(0.5)	(−1.0)	(−0.6)	(−0.6)	(2.0)
Broad dollar apprec., pre-crisis	−29.2*	−1.0	−34.4*	−4.8	−15.3	5.7
	(−3.8)	(−0.1)	(−3.7)	(−0.2)	(−1.2)	(0.5)
Broad dollar apprec., crisis	−27.4*	−24.7+	−21.6+	−3.1	−40.0*	−39.9*
	(−2.9)	(−1.7)	(−1.9)	(−0.1)	(−2.5)	(−2.9)
Crisis (dummy)	−380.2*	−225.9*	−360.6*	−509.5*	−412.4*	83.7
	(−5.2)	(−2.0)	(−4.1)	(−2.7)	(−3.4)	(0.8)
Constant	161.7*	−18.2	348.7*	480.0*	−433.9*	−593.3*
	(2.8)	(−0.2)	(5.0)	(3.2)	(−4.5)	(−7.0)
Observations	6861	2358	5136	1257	1725	1101
NCoun	44.00	15.00	33.00	8.00	11.00	7.00
R^2	0.03	0.08	0.03	0.06	0.11	0.28
AReg R^2	0.57	0.70	0.37	0.59	0.69	0.45
Wald_p(Pre-cris = Cris)	0.00	0.06	0.00	0.00	0.00	0.00

t statistics in parentheses

Notes here as needed.

$^+$ $p < 0.10$, * $p < 0.05$

Table 4A: FE Split-Sample Country-Level Panel Regressions with low-freq shipments
Includes 2008:9 and 2008:10.
FE. Dependent variable: Low-Frequency component of net shipments /GDP

	All countries	EME	FSU	Hub	Indust
Equity mkt vol, pre-crisis	18.9*	13.3*	8.0	18.3	2.0
	(9.1)	(5.9)	(1.2)	(1.3)	(0.9)
Equity mkt vol, crisis	10.3*	14.9*	−11.1	−18.9	7.2*
	(4.1)	(4.5)	(−1.1)	(−1.6)	(3.3)
Inflation, pre-crisis	8.9*	16.0*	29.2*	−104.5*	13.0*
	(7.5)	(17.7)	(3.9)	(−6.2)	(3.2)
Inflation, crisis	25.9*	47.6*	2.0	−135.2*	−9.2*
	(8.8)	(14.6)	(0.1)	(−6.1)	(−2.0)
PC: Uncert and stress, pre-crisis	−10.2+	15.1*	−119.9*	−60.5*	2.6
	(−1.7)	(2.1)	(−3.2)	(−2.4)	(0.6)
PC: Uncert and stress, crisis	23.0*	−8.7	159.0*	132.2*	9.2
	(2.7)	(−0.8)	(2.9)	(3.9)	(1.5)
PC: Uncert vs stress, pre-crisis	25.8*	−28.0*	7.0	267.2*	−0.5
	(2.3)	(−2.0)	(0.1)	(6.1)	(−0.1)
PC: Uncert vs stress, crisis	35.8*	46.4*	−20.0	115.0*	35.7*
	(3.9)	(4.0)	(−0.3)	(3.2)	(5.3)
PC: US vs Europe, pre-crisis	8.0	60.3*	−131.9	−193.9*	12.4
	(0.4)	(2.2)	(−0.9)	(−2.3)	(0.8)
PC: US vs Europe, crisis	11.0	12.8	−64.4	95.2	11.5
	(0.7)	(0.6)	(−0.6)	(1.5)	(1.0)
Global inflation, pre-crisis	−18.1*	−15.5	−166.0*	95.8*	−21.3*
	(−2.3)	(−1.6)	(−2.7)	(2.7)	(−3.4)
Global inflation, crisis	22.7*	−84.9*	400.4*	328.2*	3.6
	(2.1)	(−6.0)	(5.4)	(6.9)	(0.4)
Global GDP growth, pre-crisis	−42.2*	−24.4*	−10.2	−69.3*	−4.3
	(−7.1)	(−3.3)	(−0.3)	(−3.0)	(−1.0)
Global GDP growth, crisis	−8.0	18.8*	−46.2	−64.1*	−6.1+
	(−1.6)	(2.9)	(−1.4)	(−3.3)	(−1.7)
Broad dollar apprec., pre-crisis	0.4	5.5	43.2	−22.6	−5.0
	(0.1)	(0.8)	(1.2)	(−1.1)	(−1.3)
Broad dollar apprec., crisis	−28.6*	−13.3	−79.3+	−69.0*	−12.0*
	(−4.2)	(−1.5)	(−1.8)	(−2.5)	(−2.4)
Crisis (dummy)	−352.2*	39.4	−1485.8*	−877.1*	−117.7*
	(−6.7)	(0.6)	(−4.2)	(−4.1)	(−3.0)
Constant	149.4*	−370.7*	1270.0*	−365.8*	118.4*
	(3.6)	(−7.1)	(4.6)	(−2.1)	(3.9)
Observations	6703	1418	463	953	3125
NCoun	43.00	9.00	3.00	6.00	20.00
R^2	0.06	0.37	0.23	0.17	0.02
AReg R^2	0.71	0.68	0.59	0.69	0.08
Wald_p(Pre-cris = Cris)	0.00	0.00	0.00	0.00	0.00

t statistics in parentheses
Notes here as needed.
$^{+}$ $p < 0.10$, * $p < 0.05$

Table 4B: FE Split-Sample Country-Level Panel Regressions with low-freq shipments
Includes 2008:9 and 2008:10.
FE. Dependent variable: Low-Frequency component of net shipments /GDP

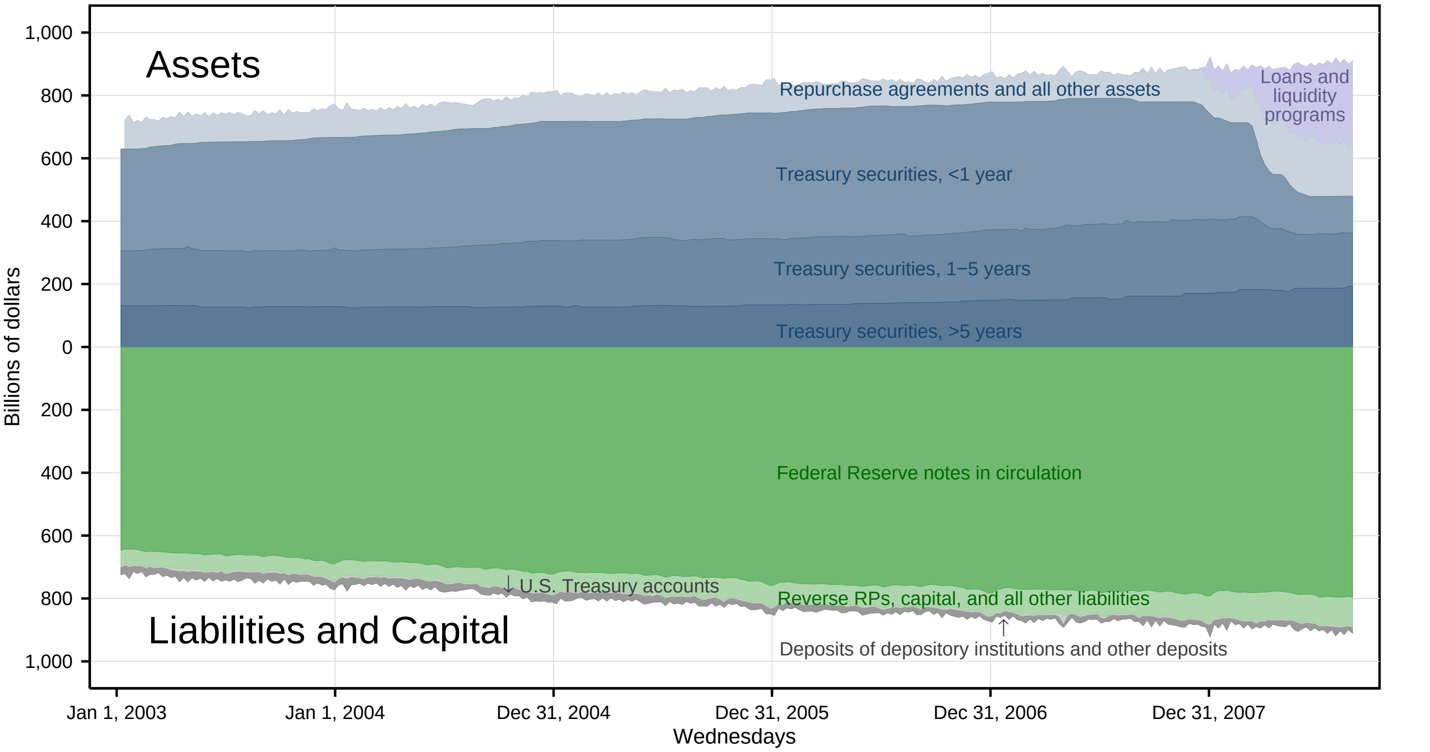
	All countries	Big	NetPos	BigPos	NetNeg	BigNeg
Equity mkt vol, pre-crisis	18.9*	11.6*	21.2*	9.0*	12.5*	13.2*
	(9.1)	(4.7)	(8.2)	(2.3)	(3.7)	(5.1)
Equity mkt vol, crisis	10.3*	11.7*	6.9*	4.0	15.6*	16.4*
	(4.1)	(3.4)	(2.2)	(0.8)	(3.7)	(4.3)
Inflation, pre-crisis	8.9*	16.0*	2.4	9.8*	12.9*	16.8*
	(7.5)	(12.4)	(1.1)	(2.9)	(9.5)	(16.3)
Inflation, crisis	25.9*	35.2*	17.3*	27.7*	54.4*	49.2*
	(8.8)	(9.6)	(4.6)	(4.7)	(10.9)	(12.0)
PC: Uncert and stress, pre-crisis	−10.2+	−17.3+	−20.1*	−51.3*	17.3+	23.0*
	(−1.7)	(−1.9)	(−2.8)	(−3.4)	(1.7)	(2.5)
PC: Uncert and stress, crisis	23.0*	21.6	27.8*	49.4*	11.2	−9.2
	(2.7)	(1.6)	(2.7)	(2.2)	(0.8)	(−0.7)
PC: Uncert vs stress, pre-crisis	25.8*	−14.1	30.4*	−0.8	12.7	−31.7+
	(2.3)	(−0.8)	(2.2)	(−0.0)	(0.7)	(−1.8)
PC: Uncert vs stress, crisis	35.8*	53.1*	27.9*	37.9	50.3*	57.0*
	(3.9)	(3.6)	(2.5)	(1.5)	(3.2)	(4.0)
PC: US vs Europe, pre-crisis	8.0	6.5	−2.1	−38.1	35.6	63.7+
	(0.4)	(0.2)	(−0.1)	(−0.7)	(0.9)	(1.8)
PC: US vs Europe, crisis	11.0	−26.5	9.2	−53.3	28.5	19.9
	(0.7)	(−1.0)	(0.5)	(−1.2)	(1.0)	(0.7)
Global inflation, pre-crisis	−18.1*	−29.0*	−8.4	−27.4	−27.9*	−19.4
	(−2.3)	(−2.3)	(−0.9)	(−1.3)	(−2.1)	(−1.6)
Global inflation, crisis	22.7*	10.4	45.5*	111.8*	−48.9*	−103.4*
	(2.1)	(0.6)	(3.5)	(3.9)	(−2.5)	(−5.9)
Global GDP growth, pre-crisis	−42.2*	−11.1	−35.8*	7.2	−57.2*	−29.7*
	(−7.1)	(−1.2)	(−5.1)	(0.5)	(−5.6)	(−3.2)
Global GDP growth, crisis	−8.0	8.0	−9.3	−7.6	−4.8	21.5*
	(−1.6)	(1.0)	(−1.6)	(−0.6)	(−0.5)	(2.7)
Broad dollar apprec., pre-crisis	0.4	10.7	−0.1	16.6	0.7	5.9
	(0.1)	(1.2)	(−0.0)	(1.2)	(0.1)	(0.7)
Broad dollar apprec., crisis	−28.6*	−29.8*	−28.3*	−37.6*	−24.2*	−14.2
	(−4.2)	(−2.7)	(−3.4)	(−2.1)	(−2.0)	(−1.3)
Crisis (dummy)	−352.2*	−212.7*	−319.9*	−457.3*	−417.5*	67.5
	(−6.7)	(−2.5)	(−5.1)	(−3.3)	(−4.6)	(0.8)
Constant	149.4*	−11.6	312.0*	406.5*	−358.6*	−499.8*
	(3.6)	(−0.2)	(6.2)	(3.7)	(−5.0)	(−7.6)
Observations	6703	2358	4978	1257	1725	1101
NCoun	43.00	15.00	32.00	8.00	11.00	7.00
R^2	0.06	0.13	0.04	0.09	0.17	0.40
AReg R^2	0.71	0.80	0.53	0.72	0.79	0.53
Wald_p(Pre-cris = Cris)	0.00	0.00	0.00	0.00	0.00	0.00

t statistics in parentheses

Notes here as needed.

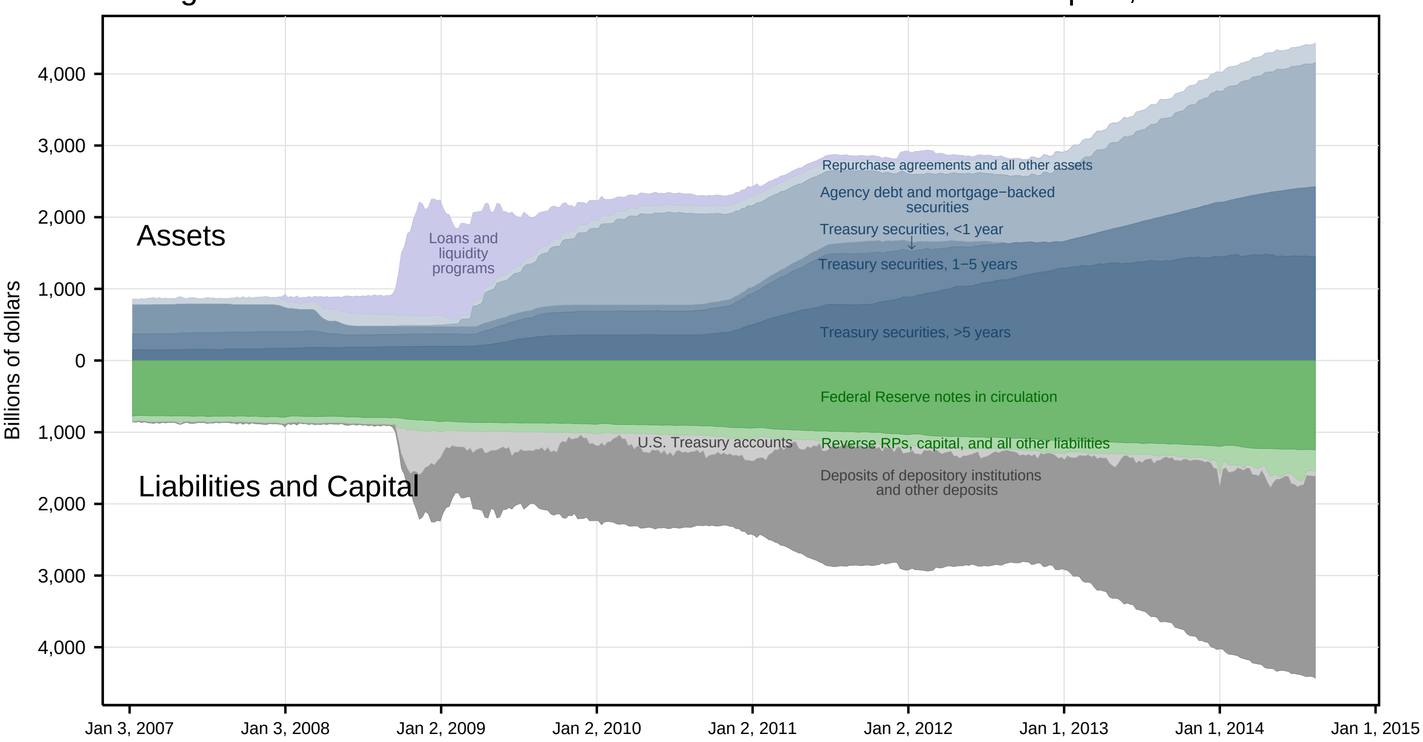
$^{+}$ $p < 0.10$, * $p < 0.05$

Figure 1A: Federal Reserve Bank Assets and Liabilities and Capital, January 2003 − August 2008



Source: H.4.1 Statistical Release (http://www.federalreserve.gov/releases/h41/). Last updated August 21, 2014.

Figure 1B: Federal Reserve Bank Assets and Liabilities and Capital, 2007 − 2014



Source: H.4.1 Statistical Release (http://www.federalreserve.gov/releases/h41/). Last updated August 21, 2014. Last observation August 13, 2014.

Figure 2

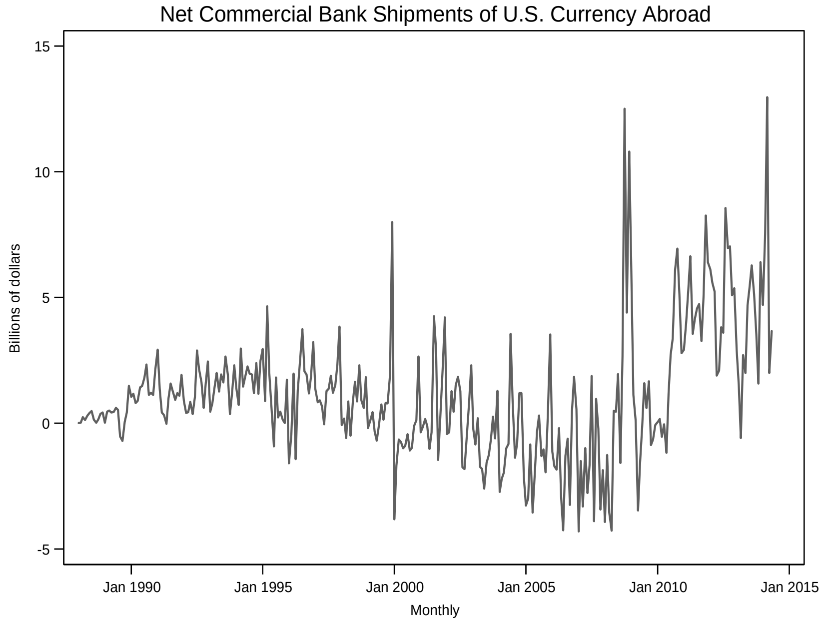
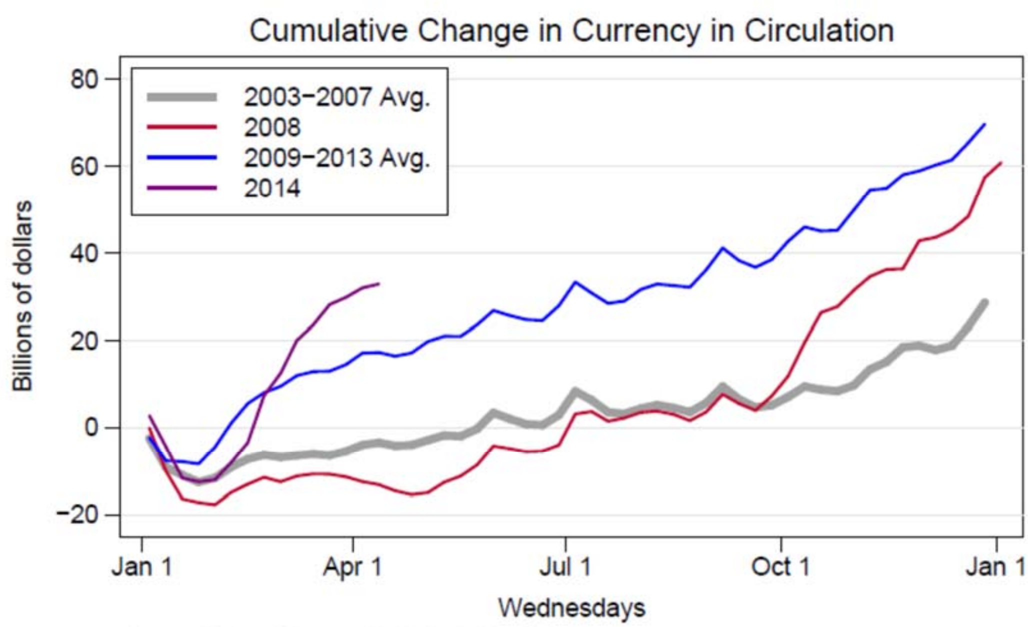
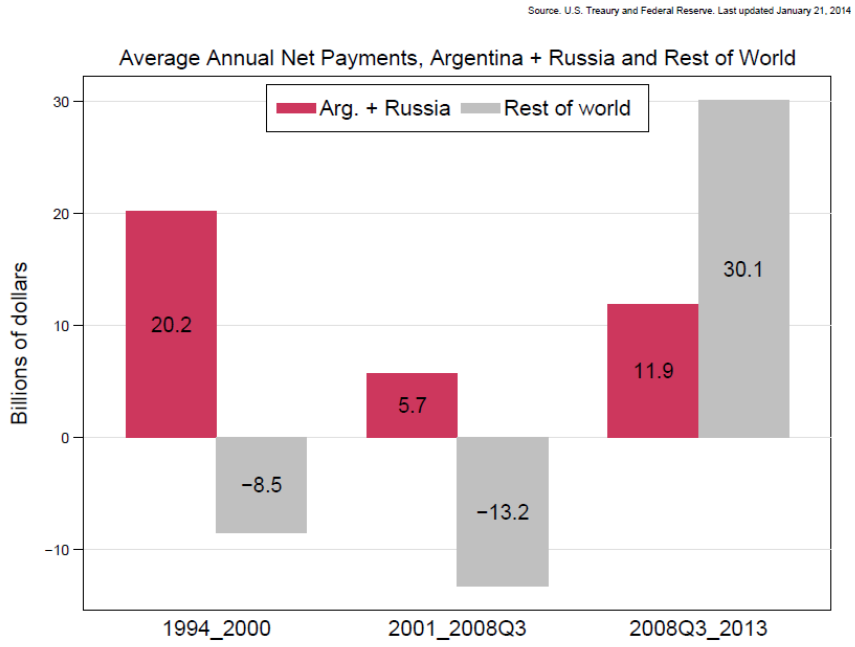


Figure 3



Source. Federal Reserve H.4.1 Statistical Release

Figure 4



Source. U.S. Treaury and Federal Reserve. Last updated January 21, 2014
Average Annual Net Payments, Argentina + Russia and Rest of World
Arg. + Russia
Rest of world
Billions of dollars
30
20
10
0
−10
20.2
−8.5
5.7
−13.2
11.9
30.1
1994_2000
2001_2008Q3
2008Q3_2013

Figure 5: Average Contributions of Local and Global Factors, by Region and Period

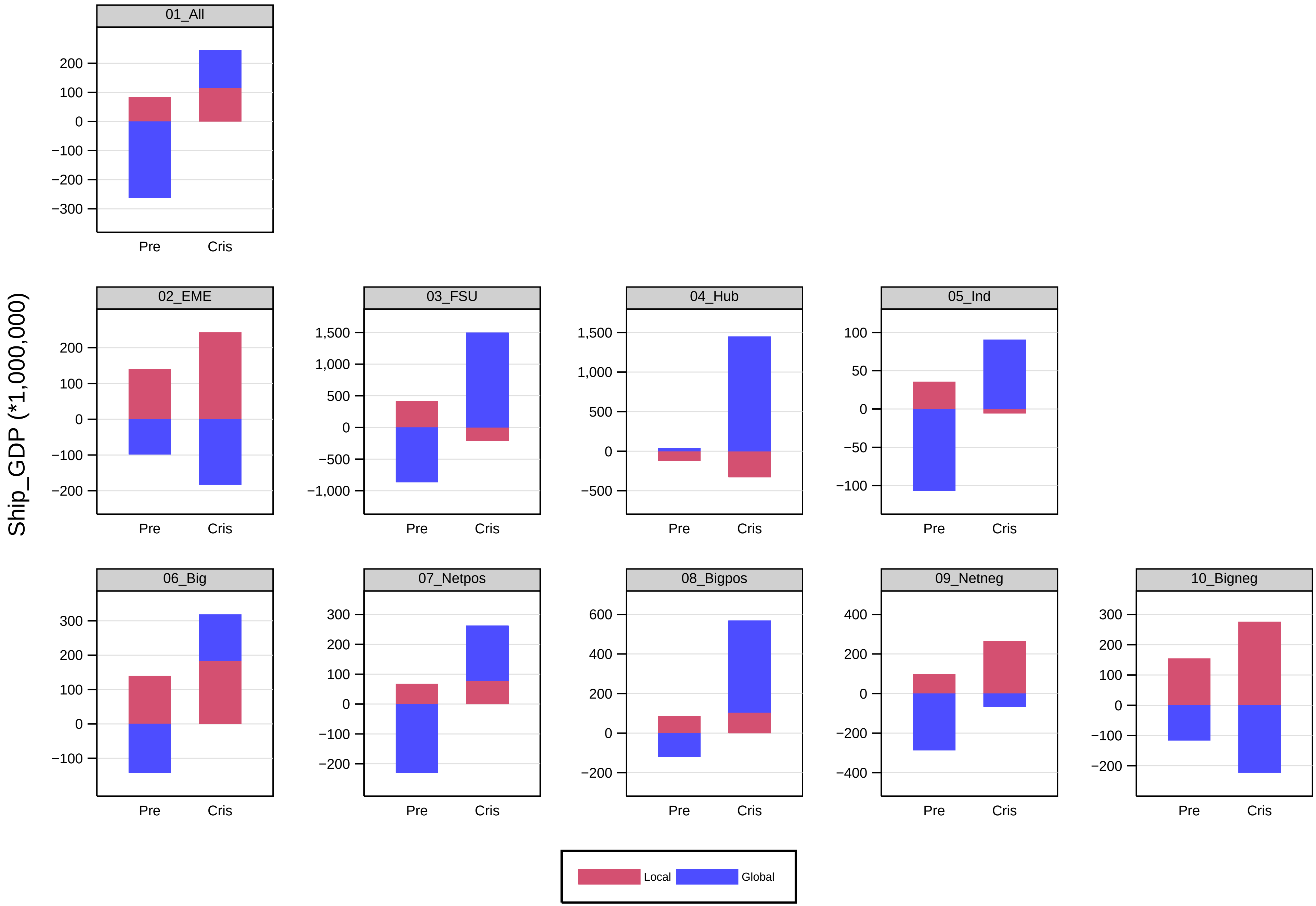


Figure 6: Average Contributions of Local and Global Factors, by Region and Period