The Death of Cash? Not So Fast: Demand for U.S. Currency at Home and Abroad, 1990-2016

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Abstract:

It would seem that physical currency should be fading out as the world of payments is increasingly electronic, with new technologies emerging at a rapid pace, and as governments look to restrictions on large-denomination notes as a way to reduce crime and tax evasion. Nonetheless, demand for U.S. dollar banknotes continues to grow, and consistently increases at times of crisis both within and outside the United States because it remains a desirable store of value and medium of exchange in times and places where local currency or bank deposits are inferior. After allowing for the effect of crises, demand for U.S. banknotes appears to be driven by the same factors as demand for other types of money, with no discernible downward trend.

In this work, I review developments in demand for U.S. currency since the collapse of Lehman Brothers in late 2008 with a focus on some new questions. First, what are the factors driving demand for lower denominations, especially $20s, which are the most commonly used in domestic transactions? To what extent can the recent strength in demand be attributed to the long spell of very low interest rates?

Finally, for the larger denominations, I revisit the question of international demand: I present the raw data available for measuring international banknote flows and presents updates on indirect methods of estimating the stock of currency held abroad. These methods continue to indicate that a large share of U.S. currency is held abroad, especially in the $100 denomination.

As shown in an earlier paper, once a country or region begins using dollars, subsequent crises result in additional inflows: the dominant sources of international demand over the past two decades are the countries and regions that were known to be heavy dollar users in the early to mid-1990s. While international demand for U.S. currency eased during the early 2000s as financial conditions improved, the abrupt return to strong international demand that began nearly a decade ago with the collapse of Lehman Brothers in 2008 has shown only limited signs of slowing. In contrast, the growth rate of demand for smaller denominations is slowing, perhaps indicating the first signs of declining domestic cash demand.

Keywords: Currency, banknotes, dollarization, crisis

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The Death of Cash? Not So Fast: Demand for U.S. Currency at Home and Abroad, 1990-2016[1]

Unlike the banknotes of most other countries, the U.S. dollar is used far beyond its borders as a medium of exchange and store of value. This international aspect of dollar usage has important implications for a wide range of Federal Reserve operational considerations, including its currency production, processing, and planning, the interpretation of currency figures as part of monetary analysis, daily open market operations, management of the Federal Reserve's portfolio, and analysis and forecasting of the Federal Reserve's income.[2] In addition, currency exports, like other exports, figure in the U.S. balance of payments and international investment position. Finally, the role of cash in the underground economy and other illicit activities has been an increasing focus of discussion, and some countries have adjusted the mix of notes they issue based on these concerns.[3] This paper shows that the post-2008 resurgence in demand for U.S. banknotes has hardly abated. In addition to updating data and methods presented in Judson (2012), this paper takes a closer look at trends by denomination and poses some additional questions about the future of cash. In particular, I note that demand for smaller denominations appears to be slowing even though interest rates are still near zero and GDP growth has been solid.

[1]This work would have been impossible without the generous assistance of, and thought-provoking discussions over many years with, Dick Porter (FRB-Chicago); Joann Freddo, Eileen Goodman, Jeff Pruiksma, Elliot Shuke, and Charles Sims (FRB-New York); Carol Bertaut, Neil Ericsson, Jaime Marquez, John Roberts, Charlie Thomas, Shaun Ferrari, Michael Lambert, and Lorelei Pagano (Board of Governors); and Edgar Feige (University of Wisconsin, Emeritus). All errors and omissions are mine.

[2] Until late 2008, Federal Reserve notes, the dominant form of currency, were the primary liability on the Federal Reserve's balance sheet. As a result, currency demand was thus a primary 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. After late 2008, deposits of depository institutions (of which reserve balances are the vast majority) increased significantly and now exceed currency as a liability on the Federal Reserve's balance sheet. Appendix Figure 3 illustrates the major components of the Federal Reserve's balance sheet since 2003.

[3] For example, India had a surprise recall of its highest-denomination notes in late 2016. The 500 euro note will be phased out after 2018.

Despite the disparate methods and data sources, the data consistently indicate several trends. First, international demand for U.S. currency increased steadily over the 1990s and into the early 2000s, a period that coincided with the fall of the Berlin Wall, the collapse of the Soviet Union, and periodic economic and political crises in several Latin American countries. Second, international demand for dollars began to stabilize or decline around the time of the introduction of the cash euro in 2002.[4] This decline coincided with economic and political stabilization and financial modernization in many economies in and around the euro zone and the former Soviet Union and continued until late 2008, when the global financial crisis sparked renewed demand for U.S. banknotes that has shown no sign of abating.

In this paper, I present estimates of the stocks and flows of U.S. currency abroad from the early 1990s through the end of 2016. Section 1 reviews the available data sources, with a focus on their strengths and weaknesses for use in answering questions about the shares of banknotes held in the United States and abroad. Section 2 presents an overview of currency demand over the past several decades and some stylized facts about the composition of U.S. currency levels and changes over time. Section 3 builds on these stylized facts and presents simple and direct estimates of stocks and flows of U.S. currency abroad. Section 4 presents updated indirect estimates of stocks and flows of U.S. currency held abroad; these estimates are based on the data sources from Section 1 as well as additional information.[5] Section 5 presents estimates of a very simple currency demand equation for the United States, from which estimates of the impact of international demand on currency growth can be derived. Section 7 reviews developments in

[4] The euro currency was introduced as a unit of account in 1999; the physical currency was introduced in 2002.

[5] It is not possible to apply the "biometric" or "fish" method to the most recent design of U.S. banknotes because of a change in the way the notes are introduced.

denominations other than $100s. Section 7 summarizes these findings and concludes with some general observations and directions for further work.

I. Data: An Overview

I.A. Total Currency in Circulation

I.A.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.[6] 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.[7] 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.

I.A.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 ($1.46 trillion of the $1.51 trillion total as of the end of

[6] 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)).

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

2016).[8] 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.[9] As shown in section 3, 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.

I.B. Data on Cross-Border Flows of U.S. Currency

Movements of currency across U.S. borders cannot be precisely measured for several reasons. First, there is no legal requirement or mechanism to monitor movements of $10,000 or less, and many individuals cross U.S. borders each year.[10] 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. Second, even when there is a legal requirement to report currency flows, mechanisms are not always in place to capture the data and reporters might not comply with requirements. Despite these challenges, informative measurements do exist.

[8] H.4.1 Statistical Release, tables 1 and 6. http://www.federalreserve.gov/releases/h41/20161229/.

[9] 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.

[10] In 2016, about 160 million passengers arrived and departed on international flights at U.S. airports and about 190 million border crossings occurred by land (Bureau of Transportation Statistics, 2017).

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 monthly, 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.

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 early 1990s. 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 level of detail in the reporting has generally improved over time as more dealers have begun to report. However, this trend has reversed in some cases in recent years as reporting banknote dealers have left the market and as other nonreporting dealers begin providing banknote shipment services to the departing reporter's customers.

Two additional 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 absence of such information complicates any estimation of regional or country-level holdings 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 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.[13]

II. Stylized Facts about U.S. Currency in Circulation

II.A. Overall Currency Growth Has Been Strong

The death of cash has often been predicted, and it would seem that demand for currency should grow somewhat more slowly than income given the general increase in the variety of payment media as well as increasing use noncash means of payment.[14] However, U.S. currency in circulation has grown at an average rate of about 7 percent annually over the past few decades,

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

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

[13] 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) and in Judson (2012), CMIRs are neither accurate nor thorough measures of large cash shipments outside the banking sector, and hence we do not use the CMIR data in this study. 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.

[14] Refer to BIS (2016).

one to two percentage points more rapidly than U.S. nominal GDP. Since 2008, the gap has been greater: annual currency growth has remained around 7 percent even though GDP growth has averaged less than 3 percent.[15]

II.B. Overall U.S. Currency Movements are Dominated by $100s

In value terms, the driving force over this period has generally been growth in the $100 denomination, as can be seen in Figures 1A and 1B.[16] Figure 1A presents annual end-year data on U.S. currency in circulation by denomination from 1989 to 2016. At the end of 2016, U.S. currency in circulation totaled about $1.5 trillion, of which nearly $1.2 trillion, or nearly 80 percent, was in the $100 denomination.[17] Figure 1B presents annual growth rates for the same items, on a fourth-quarter-to-fourth-quarter basis. The overall growth of currency, the solid black line, moves closely with, though generally more slowly than, the growth of $100 notes, the dashed purple line. The correlation of overall currency growth with $100s over this period is over 0.9; correlations with the other denominations are generally decreasing in the denomination.

II.C. Crises Are Reflected in Aggregate U.S. Currency Data

Figure 1B begins to reveal some general patterns in overall currency demand. In particular, currency growth was quite strong in the early 1990s, which coincided with the fall of the Berlin Wall and the collapse of the Soviet Union. After a brief lull in the mid-1990s,

[15] On a Q4-to-Q4 basis, over 1980-2016, currency growth averaged 7 percent and nominal GDP growth averaged 4.7 percent. Over 1990-2007, currency growth averaged 6.9 percent and nominal GDP growth averaged 5.3 percent.

[16] In piece terms, however, U.S. currency is dominated by smaller denominations. As of the end of 2016, $1s were 30% of notes in circulation, $2s to $10s were 15%, $20s were 22 percent, and $50s and $100s were 33%. Appendix Figures 1A and 1B provide a breakdown of U.S. and Canadian currency by denomination in value and piece terms.

[17] These figures are from the Treasury Bulletin: https://www.fiscal.treasury.gov/fsreports/rpt/treasBulletin/b2017_1.pdf .

currency growth picked up again in the late 1990s, driven by crisis in Argentina in 1997 and then concern about Y2K in 1998 and 1999. Following a dip in currency demand in 2000, which largely reflected the return early in 2000 of precautionary stocks accumulated late in 1999, demand was boosted in the early 2000s by the events of September 11, which, judging by outsized commercial bank shipments, led to strong overseas demand for currency in the short run and, in the longer run, the apparent accumulation of precautionary stocks at home and abroad. Demand then slowed over the mid- to late-2000s until the sharp reversal seen in late 2008.[18] More formally, Banegas, Judson, Sims, and Stebunovs (2015) show that there was a strong correlation between international demand for U.S. dollars and indexes of economic and political uncertainty over 2000-2014.

II.D. Canadian Patterns of Currency Demand Are Likely Similar to U.S. Domestic Currency Demand

One might look to Canada for evidence of what U.S. currency demand would look like without a foreign component. Canada has similar income levels, payments technologies, holiday patterns, and GDP growth rates to those in the United States, but little Canadian currency is believed to circulate externally. Figures 2A and 2B display Canadian currency in circulation by denomination in levels and growth rates from 1989 to 2016. As can be seen in Figure 2A, $100s are also prevalent in Canada, though less dramatically than in the U.S., accounting for just over half of Canadian currency in circulation at the end of 2016.[19] Overall currency growth rates for

[18] Hellerstein and Ryan (2011) find systematic relationships between currency shipments and inflation and other factors.

[19] Both the United States and Canada have notes of denominations above $100 in circulation, but in both cases, these notes have not been issued to circulation for some time.

Canada are, not surprisingly, driven less strongly by $100s and more strongly by $20s and $50s, the primary transaction denominations in Canada.

II.E. U.S. and Canadian Currency Growth Relative to Income Diverged Beginning in the 1980s

As noted earlier, U.S. currency growth has been strong even relative to nominal GDP. Figures 3 and 4 display the ratios of total currency to nominal GDP for the United States and Canada over the past half-century. Ordinary theories of money demand would predict that the ratio of income to currency, or velocity (the *inverse* of the ratio shown here) should vary positively with the opportunity cost of holding money. That is, in terms of these charts, higher opportunity cost would be associated with *lower* demand for currency relative to income. As cashless payments become more common and, presumably, more cost-effective, one might expect that, abstracting from movements in market interest rates, demand for currency relative to income should decline. Indeed, that pattern prevailed in the United States until about 1985, and in Canada generally for the period. The upturn in the U.S. ratio of currency to nominal GDP beginning in 1989 is thus anomalous and is consistent with substantial and growing external use of U.S. currency.

In the next section, I present a very simple estimate of overseas demand for U.S. currency based on these patterns and the assumption that patterns of domestic demand for currency are the same in the United States and Canada. I then juxtapose these estimates with direct measurements of cross-border currency flows.

III. Simple Estimates of Stocks and Flows of U.S. Currency Held Abroad

III.A. Two Estimates Based on Money Demand and Comparisons with Canada

III.A.1. A Very Simple Estimate

Taken together, the difference between the patterns seen for the United States and for Canada in Figures 3 and 4 suggest a simple estimate of the share of U.S. currency abroad. As noted above, and as displayed in Figure 5, U.S. and Canadian nominal GDP growth rates have been similar over this period. The observed U.S. ratio of currency to nominal GDP is the sum of domestic and foreign demand. If we assume that the Canadian ratio of currency to nominal GDP is the same as its U.S. counterpart for domestic demand, then the foreign share of U.S. demand can be estimated as follows. Define

(1) $$CURRGDP_{Canada} = \frac{CURR_{Canada}}{GDP_{Canada}}$$

(2) $$CURRGDP_{USA} = \frac{CURR_{USA}}{GDP_{USA}} = \frac{CURR_{USADom}}{GDP_{USA}} + \frac{CURR_{USAFor}}{GDP_{USA}}$$

$$= CURRGDP_{USA\_Dom} + CURRGDP_{USA\_For}$$

Replacing $CURRGDP_{USA\_Dom}$ with $CURRGDP_{Canada}$ in the equation above, it is then possible to solve for CURRUSA_For / CURRUSA_Tot as

(3) $$ForShare_{VerySimple} \equiv \frac{CurrUSA_{For}}{CurrUSA_{Total}} = 1 - (\frac{CurrGDP_{Canada}}{CurrGDP_{USA}})$$

III.A.2. A Simple Estimate

The approach above carries with it the assumption that Canadian and U.S. domestic demand for currency are the same at the same point in time. However, the level of Canadian per capita income, while similar to that of the United States, has generally been a bit lower. Thus, an

alternative assumption would be that Canadian and U.S. domestic demands for currency relative to income are the same at the same levels of per capita income. In order to construct an estimate of the share of U.S. currency abroad using this assumption, we proceed as follows. First we regress the ratio of Canadian currency to GDP on the log and level of Canadian per capita GDP, denoted GDPC:

$$(4) \quad CURRGDP_{Canada} = \alpha_{Canada} + \beta_1 lnGDPC_{Canada} + \beta_2 GDPC_{Canada} + \varepsilon_t$$

To be sure, this specification is a very simple reduced form based on the chart shown; it effectively assumes a log-linear structure for demand for currency as a function of income and assumes no other factors. We then construct the estimated domestic share of U.S currency for a given level of GDPC as

$$(5) \quad \widehat{CURRGDP_{USADom}} = \alpha_{Canada} + \beta ln(GDPC_{USA} * X_{CanUS})$$

where X_{CanUS} is the U.S.-Canadian dollar exchange rate. The simple estimate is then constructed as before, replacing $CURRGDP_{USADom}$ with $\widehat{CURRGDP_{USADom}}$ rather than $CurrGPD_{Can}$ in Equation 2 and rearranging to solve for $CURR_{USAFor}$ / $CURR_{USATot}$, which gives

$$(6) \quad ForShare_{Simple} \equiv \frac{CurrUSA_{For}}{CurrUSA_{Total}} = 1 - \left(\frac{\widehat{CurrGDP_{USADom}}}{CurrGDP_{US}}\right)$$

These two estimates of U.S. currency abroad are displayed in Figures 6A and 6B. The GDP-based estimates, the solid lines, suggest that about 60 percent of all U.S. currency, and about 75 percent of $100s, were held abroad as of the end of 2016, for a total value of about $900 billion. Over the past two decades, these estimates point to a sharp runup in external demand for U.S. currency beginning in the late 1980s, a brief pop in 1999, a decline beginning in 2003, and a resurgence in 2008 that continued through 2016, all patterns consistent with the overall growth of U.S. currency.

III.B. Measurements of Cross-Border Flows of U.S. Currency

We now turn to the information provided by direct measurements of currency flows. Figures 7 through 11 display annual data on the primary measurements of cross-border currency flows in dollars, the international commercial bank shipment data described in Section I.B.1. Beginning with Figure 7, the solid black line indicates net commercial bank shipments and the dashed blue line indicates the total change in currency in circulation each year.[20] Focusing only on the solid black and blue dashed lines, several features of the data stand out. First, reflecting the strong influence that international demand has on overall U.S. currency demand, the two series generally move in parallel, though the gap widens in the early 2000s and narrows in the most recent years. Second, the spike seen in total currency in circulation around 2000, the blue dashed line, is absent in the shipment flows. This feature of the data reflects the fact that a large share of the runup in holdings of currency immediately prior to the century date change (that is, in the final weeks of 1999) was held in commercial bank vaults and was then returned to the Federal Reserve early in 2000. Thus, while the currency was technically "in circulation" in the sense that it was held outside the Federal Reserve, the bulk of it never went to bank customers.[21]

While U.S. currency is used in, and is shipped to and from, many countries, a few areas stand out because of their size and their appetite for dollars in times of crisis. In Figure 8, the dashed red line indicates net commercial bank shipments to the two leading markets in this category, the former Soviet Union and Argentina. For all but the first and last few years of the period shown, or from about 1995 to 2008, these shipments more than fully accounted for all net

[20] Net commercial bank shipments are defined as shipments out of the United States to other countries (exports) less shipments from other countries into the United States (imports).

[21] For many internal calculations, we typically smooth through this spike because of its extremely transitory and peculiar nature. The currency component of the money stock excludes currency held in the vaults of depository institutions. We would ordinarily prefer to use this currency component measurement, but data are not available by denomination on that basis.

commercial bank shipments. This phenomenon might also have been the case in the early part of the sample, but reporting in that period was not as detailed. As a result, shipments recorded with a destination of Europe might well have been sent to the former Soviet Union. In the early 2000s, net shipments to these markets declined as the financial conditions stabilized and as the need to use cash for saving and transactions has faded. In the past two years, though, global conditions as well as crisis and political uncertainty in these regions appears to have coincided with an upswing in demand for dollars.[22]

Figure 9 displays a proxy for commercial bank shipments based on currency processing data, the solid gray line. Commercial bank shipments are reported on a confidential basis, and monthly data are not always available on a consistent schedule. In order to have data for operational and publication purposes, Federal Reserve Board staff developed this proxy, which is the sum of net payments of $100 notes from three Federal Reserve offices known to handle substantial volumes of deposits and withdrawals sent from or to international destinations: New York, Los Angeles, and Miami.[23] This proxy is based on two assumptions, which differ from the true net shipments series in two offsetting ways. The first assumption, which likely results in an overestimate, is that all payments and receipts at these offices are to or from international counterparties and that all payments and receipts at other offices are to or from domestic entities; in fact, every Federal Reserve office serves domestic and international customers. The second assumption, which would generally result in an underestimate, is that only $100s are sent to or received from international destinations. This proxy moved very closely with the total shipments

[22] See Banegas et al. (2015) for analysis of the significance internal and external economic and political crisis for currency demand at the global and country level.

[23] The Federal Reserve System has 12 regional Banks, whose locations are fixed. Many Federal Reserve Banks also have one or more branches, whose number and location can change over time as operational needs dictate. The Miami office is a branch of the Federal Reserve Bank of Atlanta and the Los Angeles office is a branch of the Federal Reserve Bank of San Francisco.

data in the 1990s, but was considerably higher than shipments over most of the 2000s, perhaps suggesting that domestic demand for $100s was stronger in that period.

The two dashed series in Figure 9 indicate two experimental series. As noted above, one shortcoming of the shipment dataset is that it captures only cross-border flows carried through commercial banking, or "wholesale" channels. However, as reported in U.S. Treasury (2006), many countries receive large dollar flows through nonbank, or "retail" channels and return dollars to the United States through banking channels. In the commercial bank shipment data, this phenomenon emerges in the form of persistent negative net shipment figures. That is, the shipment figures indicate large flows of dollars out of the foreign country into the United States and much smaller flows in the opposite direction.

For some such countries, the net commercial bank shipments figures are likely accurate and reflect dollar banknote inflows from third countries. For example, if tourists from Country A routinely carry dollars to Country B and the residents of Country B have little other use for dollars, the dollars might be shipped from Country B to the United States. All other factors equal, this pattern would result in negative net shipments figures, and shipments figures summed across Country A and Country B would give an accurate indicate of flows into and out of the United States. For some countries, however, it is likely that dollars arrived in the country from the United States through nonbank channels. In such cases, the commercial banknote flows would not give an accurate indication of net flows to and from the United States.

The first experimental series imposes a very rough adjustment for this phenomenon as follows. First, a group of countries known to have significant tourism or significant populations of immigrants or migrant workers in the United States is identified. Second, a group of countries whose total net shipments is substantial and negative is identified. Third, for each year and for

each country in both groups, the assumption is imposed that total net currency shipments to these countries, including the observed net commercial bank "wholesale" flows and nonbank "retail" flows, were zero.

As with the shipments proxy, this approach embodies two assumptions. First, this approach implicitly assigns a value of zero for net currency flows to these countries. This assumption could be erroneous in either direction: actual net flows could be positive or negative. Second, this approach assumes that other countries' flows in aggregate are accurately measured by net commercial bank shipments. The blue dashed line shown here displays an adjustment that imposes this assumption for about a dozen countries. While this approach is admittedly crude, it is suggestive of the magnitude of flows that could be occurring through nonbank, or "retail" channels. Ideally, we could refine this measure by constructing series of "retail" (nonbank channel) banknote flows from the United States to other countries. While this type of data is not available universally, it is collected by some countries, including Mexico.[24] This measure, the dashed black line, also tracks the shipments proxy for most of the sample, though it becomes implausibly large in the last few years of the sample. To the extent that this adjustment it useful, it is probably more applicable for cumulative, or stock estimates, than it is for flow estimates, because the nonbank flows likely occur at different times than the measured banking-channel flows back to the United States. For example, currency might be brought from the United States

[24] Mexico is the largest single contributor to this adjustment, and it was the case of Mexico that inspired this approach. In the 1990s, Mexico collected customs data on cash imports from all travelers with no lower bound on the reporting threshold. This reporting is, of course, subject to the same problems of underreporting as other customs data, but the magnitudes were substantial and of a magnitude similar to reported commercial bank inflows. More recent customs reporting requires only declaration of amounts above $10,000. Regardless, Mexican statistics on tourism flows indicate substantial volumes of people and revenue, though the form of the revenue (cash, credit card, or other) is not specified. Refer to Banco de Mexico (2012).

to another country through nonbanking channels over time and then return quickly in the event of a regulatory or other political or economic change.

Finally, the dashed gray line is an adjusted shipment proxy series. Along the lines of the adjusted commercial bank series, this series includes only payments of $100s from the Federal Reserve Bank of New York, which are generally positive, and omits payments from the Miami and Los Angeles cash offices, which are generally negative and might reflect reflows of currency that moved across U.S. borders through nonbank channels.

Figures 7 through 9 display nominal values, which can be misleading even in a period with relatively low inflation. Figure 10, therefore, displays all of the same series as in Figures 7 through 9, but scaled by the stock of currency in circulation at the end of the previous year, or the approximate percentage-point contribution to currency growth that would be implied by each of these measures. While the measures certainly vary, they generally point to strong contributions from foreign demand in the early to mid-1990s, a slowing in the mid-2000s, and a resurgence beginning in 2008.

III.C. Using Cross-Border Flow Estimates to Construct Estimates of the Stock of U.S. Currency Abroad

While tracking movements in currency in circulation is the major object of operational interest, having an estimate of the stock of U.S. currency abroad is also important for various analytical and operational questions faced by the Federal Reserve. Figures 11A and 11B chart the stocks of currency in circulation implied by the flow measures presented earlier. In Figure 11A, each line represents the cumulative change in the item since the end of 1988, when currency in circulation was about $230 billion. As indicated by the thicker gray dashed line, total U.S. currency in circulation worldwide has increased by about $1.2 trillion since 1990. The

most direct measurement, commercial bank shipments, the solid black line, suggests that nearly $500 billion has moved abroad since 1990, which would put the total at between $500 billion and $700 billion, depending on the assumed initial value. The shipments proxy, the solid gray line, suggests that about $600 billion moved abroad over the period, putting the total at $600 billion to $800 billion.[25] Finally, the adjusted shipments and proxy figures, the dashed black and gray lines respectively, suggest that about $750 to $900 billion moved abroad over the period, putting the total at $750 billion to $1.1 trillion. These ranges are, of course, large, though the simple method proposed above in Section III.A.2 produces an estimate very close to the center of the range.

Finally, Figure 11B displays the cumulative flow measurement and estimates as a share of the cumulative increase in currency in circulation at each point in time. Again, the estimates are disparate, but indicate some common trends, including a strong role for international demand in the 1990s, a waning role in the early 2000s, and a resurgence in 2008 that shows signs of stabilizing but not waning. In this Figure, as earlier, the role of the former Soviet Union and Argentina is likely understated because of poor data coverage in the shipment data in the early 1990s.

IV. Indirect Estimates of the Share of U.S. Currency: The Seasonal Method

Earlier work on estimates of the stock of currency abroad has developed and provided estimates from two methods, known as the seasonal method and the biometric method.[26] Updates to these methods continue to indicate that a substantial share of U.S. currency is abroad,

[25] The proxy is the only measurement available before 1988. It indicates that $40 billion moved abroad over the period from 1974 to 1989; during that time, currency in circulation increased by about $180 billion.

[26] Refer to Porter and Judson (1996), Judson and Porter (2001), U.S. Treasury (2006).

but technical factors and shifting patterns of currency demand have made their use more challenging.

In particular, this paper does not present estimates based on the biometric ("fish") method because current banknote distribution practice does not allow use of one of the critical assumptions. In particular, the biometric method relies on the assumption that, when a new banknote series is issued, all banknotes issued are of that series. However, for the issuance of 2003-series $20s, $50s, and $100s, older designs co-circulated for a time, and so it is not currently feasible to produce these estimates for the current design.

IV.A. The Seasonal Method: Key Assumptions

The seasonal method extracts an estimate of the share of U.S. currency abroad by working from four key assumptions. First, we assume that the seasonal pattern in domestic demand for U.S. dollars is similar to the seasonal pattern of demand within Canada for Canadian dollars (similar holidays, vacations, customs, and denominations). More specifically, we assume that the seasonal amplitude, or the percentage difference between the seasonal peak and seasonal trough, is similar for U.S. and Canadian currency demand.[27] Second, we assume that foreign demand for U.S. dollars has no significant seasonal pattern, or, correspondingly, that the seasonal amplitude for the foreign component of demand for U.S. dollars is zero. Third, we assume that circulation of Canadian dollars outside of Canada is negligible, so that the demand for Canadian dollars can be attributed solely to domestic demand. Finally, we assume that U.S. currency is not used to a substantial degree inside Canada.

[27] Of course, Canadian and U.S. holidays are not identical: to give just two examples, Canada observes Thanksgiving in October and the U.S. observes it in November, and Canada's holidays include the day after Easter and the day after Christmas while these days are not generally holidays in the United States. Nonetheless, the broad outlines of holidays are very similar, especially at a monthly frequency.

IV.B. Model

Based on these assumptions, we can express the seasonal model as follows:

Define:
S_i^j = seasonal amplitude for country i, component j
β_t = fraction of currency held abroad at time t

The overall seasonal amplitude in U.S. currency, S_{US}^T, can be expressed as a weighted sum of domestic (d) and foreign (f) components:

(S1) $S_{US,t}^T = \beta_t S_{US,t}^f + (1-\beta) S_{US,t}^d$

We cannot separately identify $S^f_{US,t}$ and $S^d_{US,t}$ but, using the assumptions above, we replace $S^f_{US,t}$ with 0 and $S^d_{US,t}$ with $S^T_{Can,t}$ to obtain:

(S2) $S_{US,t}^T = \beta_t * 0 + (1-\beta) S_{Can,t}^T$

Or, solving for β_t:

(S3) $\beta_t = 1 - \frac{S_{US,t}^T}{S_{Can,t}^T}$

IV.C. Application and Estimates

We estimate the share of all currency abroad and the share of $100s abroad using X-12 ARIMA and an alternative shorter smoothing window to obtain seasonal factors for U.S. and Canadian currency in circulation. Once the seasonal factors are estimated, the seasonal amplitude must be calculated.

In earlier estimates using this method, the peak month was December and the trough month was February of the following year. However, it seems that seasonal factor patterns have changed in the past several years, as illustrated in Figures 12A and 12B. December remains the clear peak, though its relative magnitude has declined precipitously. February is no longer the trough for U.S. currency in circulation. Rather, September is now the trough, though January is

now about the same as September. Since this method requires that the same "peak" and "trough" months be chosen, I use December and January.

Because of these shifts over time, I propose two approaches to measuring the seasonal amplitude. For each, I report results using two different seasonal adjustment procedures, X12-ARIMA and X12 with a shorter 3x1 smoothing window, shown in black and blue respectively. The first approach estimates the annual amplitude as the difference between the seasonal factor for December of one year and January of the next year. These estimates are associated with the year in which December falls and are shown in Figures 13A and 13B as the "annual" estimate, the solid lines. A third approach is to estimate the seasonal amplitude each month as the difference between the maximum and minimum seasonal factors over the most recent twelve months, and then to estimate the monthly share of currency abroad as the trailing average of the estimates for the past twelve months. The estimates from this approach are shown in Figures 13A and 13B as the "monthly" short-dashed lines. [28] [29]

The results of the seasonal estimates for all currency abroad and for $100s through December 2016 are displayed in Figures 13A and 13B. As was the case in earlier work, these estimates are on the high end of the range. These estimates also show a quite different time series pattern relative to one another as well as relative to other flow-based measures, though the monthly measures generally indicate an upswing in the share of U.S. dollars held abroad.

[28] In this method, one could just as easily use the unsmoothed seasonal amplitude estimates. These estimates, though, show a step-function-like shape because the seasonal maximums and minimums generally change once per year. It seems unlikely that the share of currency abroad follows such a step function, and so the moving average imposes a smooth trend. Notably, this averaging does not affect the level of the share estimates on average over time.

[29] A third method presented in Judson (2012) has been dropped because it is now producing unrealistic estimates that approach 100 percent.

One curious feature of these results is that the estimates for $100s are lower than the estimates for currency overall despite our general impression that $100s are more prevalent in international use of U.S. currency. It is difficult to know what to make of these results, though it seems likely that it is related to the quite substantial changes in seasonal amplitudes evident in both the U.S. and Canadian data. This topic is worthy of study in its own right.

V. Estimating a Currency Demand Function

Finally, we return to the idea of a currency demand function, which was briefly explored in Section 3 with reference to Canada. Here, the approach is to specify a demand function for U.S. currency that allows for foreign shipments as well as domestic factors. Our general assumption has been that currency demand consists of two components: a domestic component, which should be correlated with the typical determinants of money demand; and an international component, which is driven by routine as well as crisis-related fluctuations in foreign demand for U.S. currency.

Table 1 presents coefficient estimates for a simple error correction model for the currency component of M2 estimated quarterly beginning in 1988, a date chosen for two reasons.[30] First, 1988 marks the beginning of availability of the commercial bank shipment data as well as an apparent upshift in international demand for U.S. currency. Second, preliminary testing (not shown) indicates a distinct structural break in 1988. The regression model consists of two equations, one for the steady state and one for dynamics.

[30] As noted in Section III.B., the currency component of M2 excludes currency held in the vaults of depository institutions, or vault cash, which was one of the most volatile components of currency in circulation just before and after the century date change. Thus, this measurement of currency is more useful for longer-term analysis where the inclusion of the large and transitory swings in vault cash might be inordinately influential, such as in quarterly measurements where the periods immediately before and immediately after the century date change fall into different quarters.

The steady state equation is

$$Log(NGDP) - Log(Curr) = \alpha_0 + \alpha_1(R_{short}) + \alpha_2 Trend - \varepsilon_t$$

The dynamic equation is

$$d(\log(Curr)) = \beta_0 \varepsilon_{t-1} + \beta_1 SHIP + \beta_2 (d(\log(Curr))_{t-1} + \beta_3 d(\log(NGDP)_{t-1} + \beta_4 d(\log(NGDP))_{t-4} + \beta_5 Y2K + \nu_t$$

Table 1: Quarterly Error Correction Regression Results
Dependent variable: Growth of seasonally adjusted currency component of M2
Quarterly, 1988:1 – 2016:4

	Coefficient	T-Stat
Steady – state equation		
α_0 (Constant)	6.293	6.8
α_1 (R_{short})	0.031	2.1
α_2 (Trend)	-0.003	-3.0
Dynamic equation		
β_0 (Error correction coefficient)	-0.026	-2.7
β_1 (Shipments)	0.534	8.9
β_2 (Y2K Dummy)	0.004	1.1
β_3 $(d(\log(Curr))_{t-1}$	0.558	10.3
β_4 $d(\log(NGDP))_{t-1}$	0.200	3.5
β_5 $d(\log(NGDP))_{t-4}$	0.241	--
Adjusted R-squared = 0.70		
Number of obs = 116		

The variables are defined as follows:

- NGDP: Nominal GDP, seasonally adjusted
- Curr: Seasonally adjusted currency component of M2
- SHIP: Two-month moving average of commercial bank shipments adjusted for negative net shipments, divided by the previous period's seasonally adjusted currency component of M2. This formulation puts shipments on the same basis as the monetary aggregate growth data, which are calculated as monthly averages.
- Rshort: Short-term interest rate, a proxy for the opportunity cost of holding currency
- Trend: 1 for 1988:Q1 and increasing by 1 each quarter

- Y2K: Dummy: 1 for 1999:Q4 and -1 for 2000:Q1

The coefficients in the steady state equation are constrained to unitary elasticity, and the coefficients on the lagged values of log changes in currency and GDP are constrained to sum to 1. The equations are estimated by nonlinear least squares in one step by substituting for the error term in the dynamic equation. After controlling for the estimated contribution of overseas demand, the coefficients are generally of the expected sign and magnitude. The short interest rate is positively correlated with velocity, the error correction coefficient is negative, shipments are strongly significant, and recent lags of currency growth and income are significant. The time trend coefficient is somewhat counterintuitive, but its overall contribution is small and so we leave further examination of it for future work.

Figure 14A displays overall currency growth, the solid black line, the proxy measurement, the short-dashed red line, and nominal GDP growth, the dashed gray line, for the regression sample period. Finally, Figures 14B and 14C display the quarterly and cumulative contributions to currency growth from foreign demand implied by the regression in Table 1. In both figures, the contributions are calculated from dynamic forecasts with residuals applied equally to the two components. As indicated by the dashed red line in Figure 14C, international shipments, as measured by the $100s proxy, are responsible for about two thirds of the growth in currency over this period.

Notably, even the highest of these estimates suggests that currency holdings by U.S. residents are significant—at least $1,000 per person—a finding at odds with survey work on currency holdings.[31] Feige (1996, 2012) suggests that underground economic activity could

[31] The most recent Survey of Consumer Payment Choice, conducted in 2014, indicates holdings of about $200 per person (Greene et al., 2014).

account for this discrepancy, though underreporting, especially by individuals with large cash holdings, is also likely a substantial problem.

VI. The End of Cash? Demand for U.S. Currency by Denomination

While $100s are the largest denomination by value and dominate international flows, the evolution of demand for smaller denominations in recent years deserves examination. Figure 15 displays the ratio of currency to U.S. nominal GDP from 1960 to 2016 for all currency, for $100s, for $20s, and for $10s and below. Not surprisingly, the path for total currency closely tracks that for $100s, with a steady upward path. In contrast, the path for $20s shows a slight uptick in the mid-2000s after years of steady decline, and the paths for $10s and smaller shows signs of leveling off or even declining.

Focusing on growth rates gives a slightly different picture: as seen in Figure 16, which displays growth rates for the same denomination groups, currency demand growth has been slowing somewhat. While demand for $50s and $100s is still growing faster than in the 2000-2007 period, it is now slower than in earlier decades. The pattern is similar for $20s, with growth edging back down. For the smallest denominations, growth is closer to earlier trends, but remains at or below the rate of GDP growth.

These trends are of relatively short duration, and it remains far too early to announce the death of cash. It is possible that demand growth will pick up with nominal GDP, but it is also possible that rising interest rates will limit growth. In addition, international demand is as difficult to predict as crises themselves, but the slowing growth rate of demand for $100s is notable.

VII. Summary, Conclusions, and Directions for Future Work

In sum, much as in earlier work, the currently available data do not allow for precise estimates of foreign holdings of U.S. currency, and the available estimates are somewhat disparate. Nonetheless, direct measurements, regression-based estimates, and indirect estimates all point to strong international demand in the 1990s, a falloff in the early 2000s, and a resurgence that coincided with the collapse of Lehman Brothers and has yet, nearly ten years later, to subside.[32] Collectively, these methods continue to suggest that half or a bit more than half of U.S. currency circulates abroad. For the U.S. dollar, the end of strong demand both abroad and at home seems to be far off, though, as noted, demand growth is slowing.

There are many promising avenues for future investigation, including the following. First, is there a good way to estimate hoarding of notes, using the biometric method or some other method based on banknote processing data? For the biometric method, what might we be able to learn about hoarding of notes? For the seasonal method, what is the significance, if any, of the shift observed in seasonal patterns of demand for U.S. currency? For the regression-based methods, would a more rigorous and sophisticated regression framework yield more precise or very different estimates? Are there ways to tease out the drivers of cash abroad? It is often asserted that cash is overwhelmingly used for illicit purposes, but can the forces driving licit and illicit use be identified and measured? Finally, as more and more ordinary transactions become cashless, will cash be increasingly marginalized?

[32] Indeed, weekly data, reported in Appendix Figure 2, show an unmistakable turnaround in demand patterns in the middle of September 2008.

Appendix: 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 table 1. None of these sources provides any information about domestic and international movements of U.S. currency.

Appendix Table 1: 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

Appendix Table 1: Public data sources on U.S. currency in circulation						
Publication name	**Source**	**URL**	**Frequency**	**Date Range**	**Definition**	**By denom-ination?**
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	
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

Appendix Table 1: Public data sources on U.S. currency in circulation						
Publication name	**Source**	**URL**	**Frequency**	**Date Range**	**Definition**	**By denom-ination?**
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.

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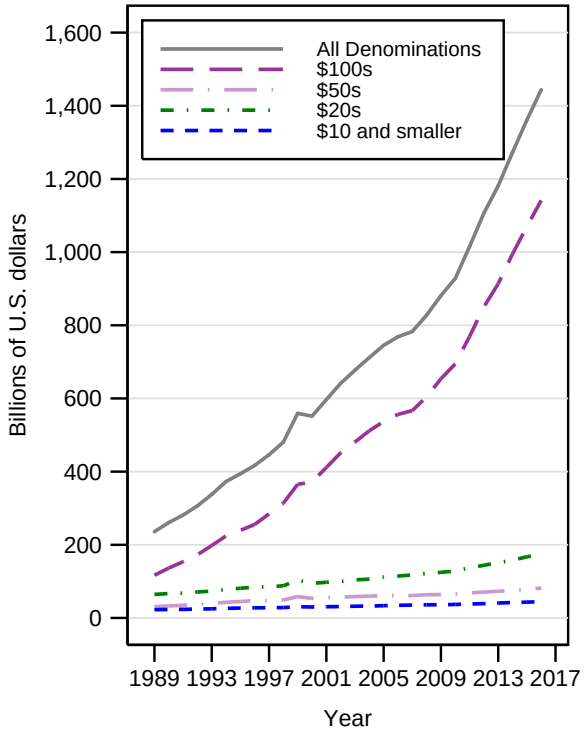
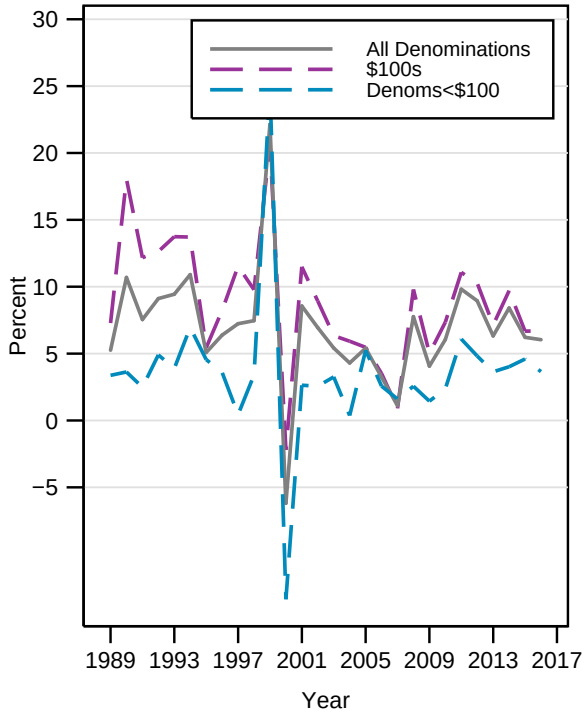
Figure 1A: U.S. Currency Levels, 1989−2016



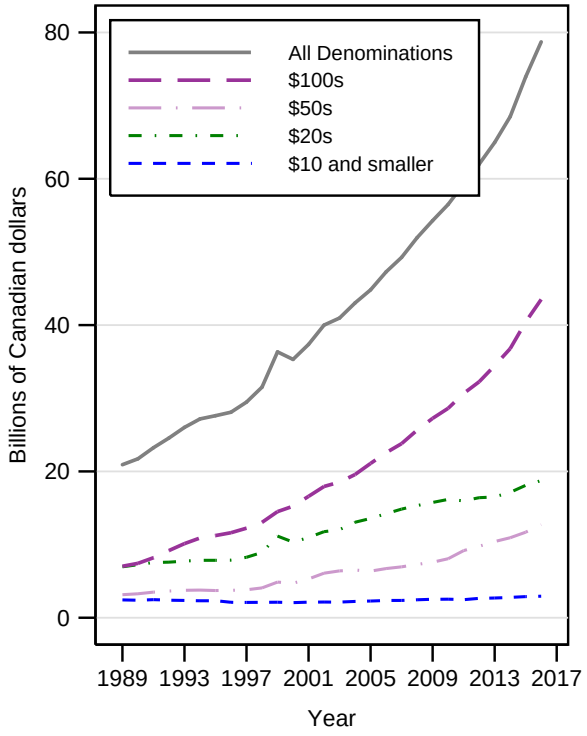
Note. Average of Sept. and Dec. currency in circulation.

Figure 1B: Annual Growth of U.S. Currency, 1989−2016



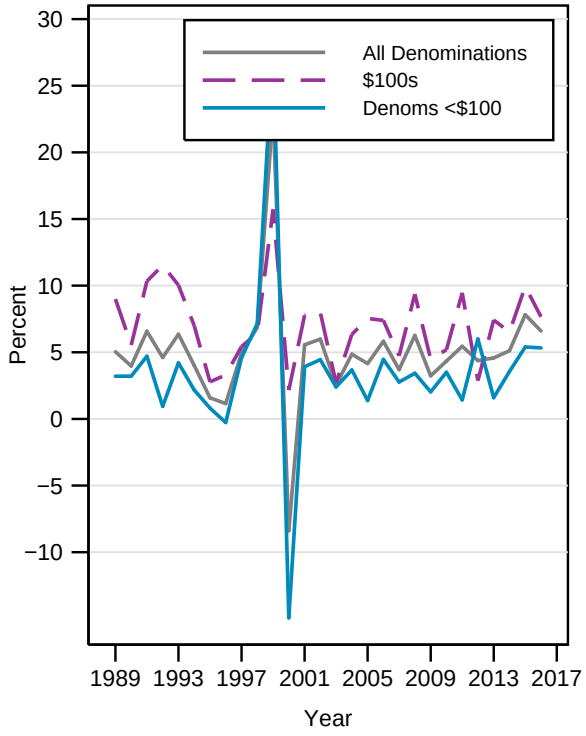
Note. Annual growth rates of fourth−quarter averages (average of end−September and end−December levels).

Figure 2A: Canadian Currency Levels, 1989−2016



Note. Average of Sept. and Dec. currency in circulation.

Figure 2B: Annual Growth, Canadian Currency, 1989−2016



Note. Annual growth rates of fourth−quarter averages.

Figure 3: U.S. Currency to Nominal GDP Ratios, 1960−2016

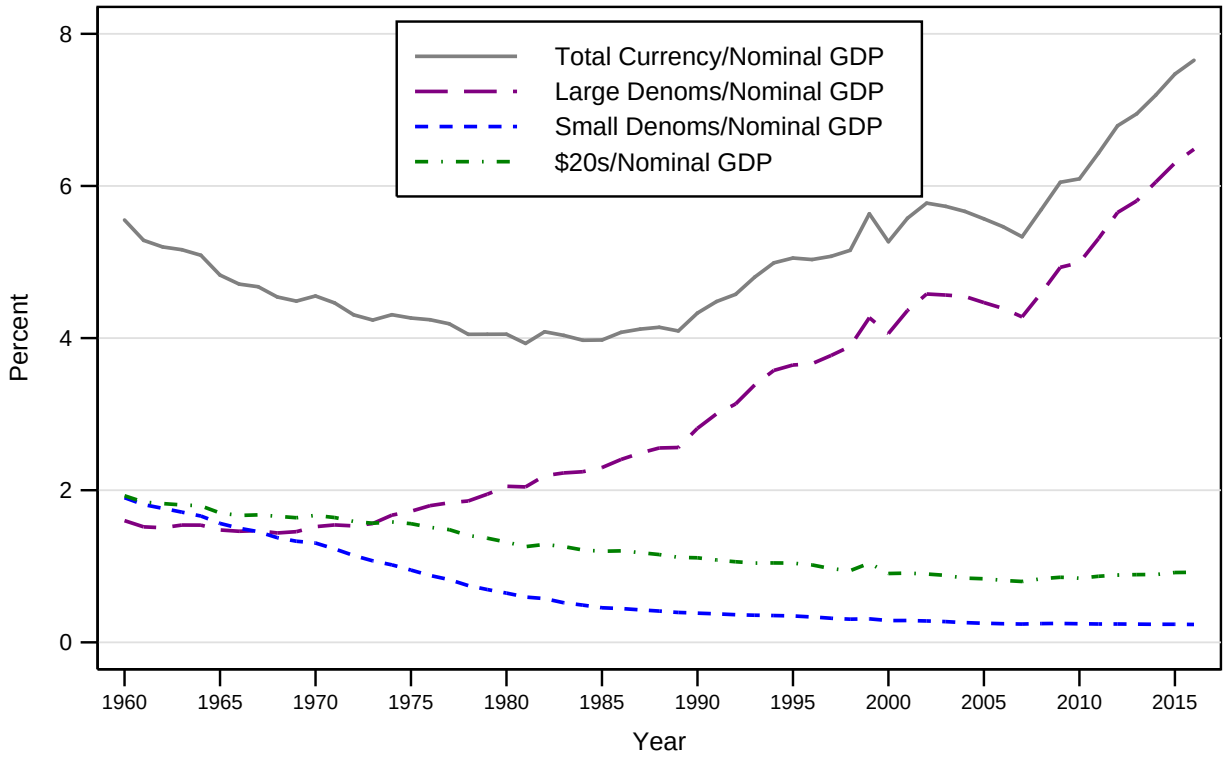


Figure 4: Canadian Currency to Nominal GDP Ratios, 1960−2016

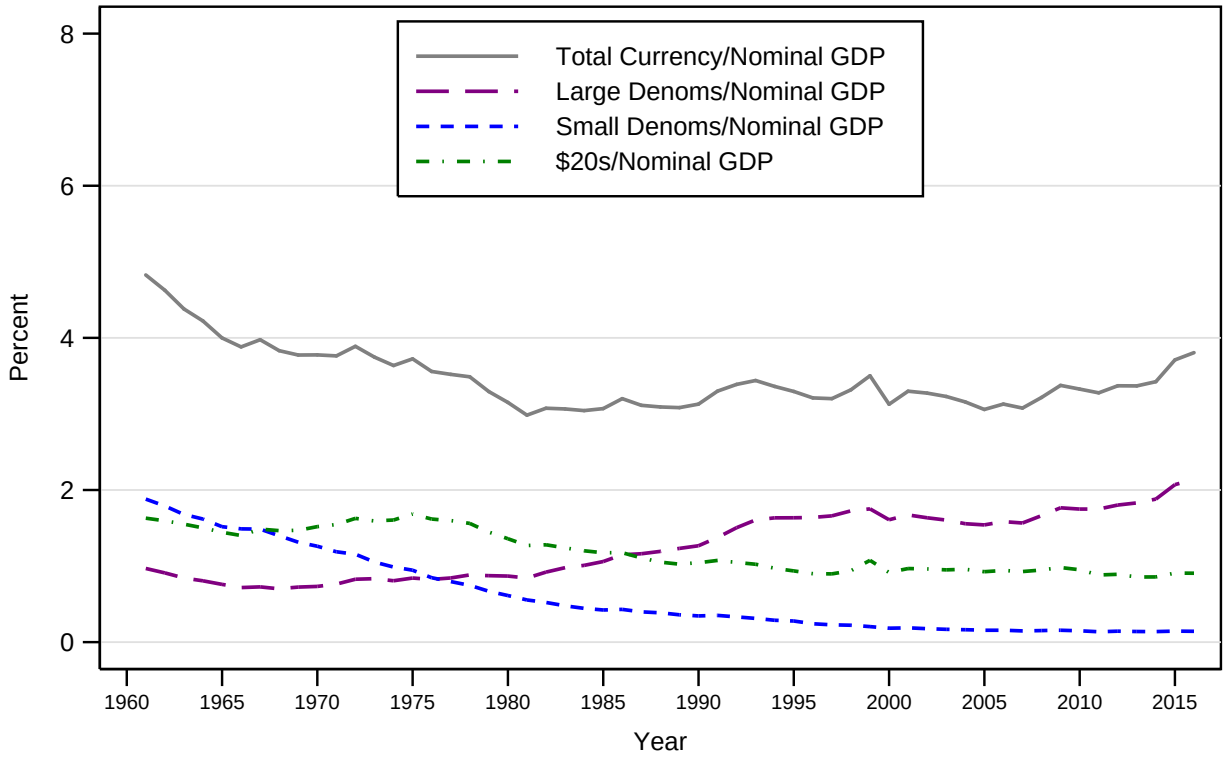


Figure 5: Growth Rates of U.S. and Canadian Nominal GDP, 1960−2016

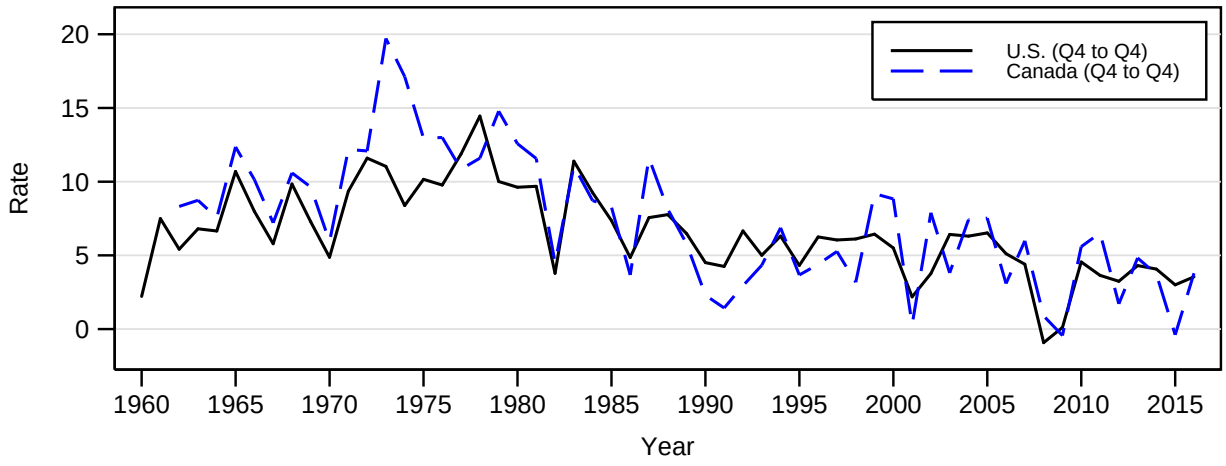


Figure 6A: Simple Estimates of the Share of U.S. Currency Abroad

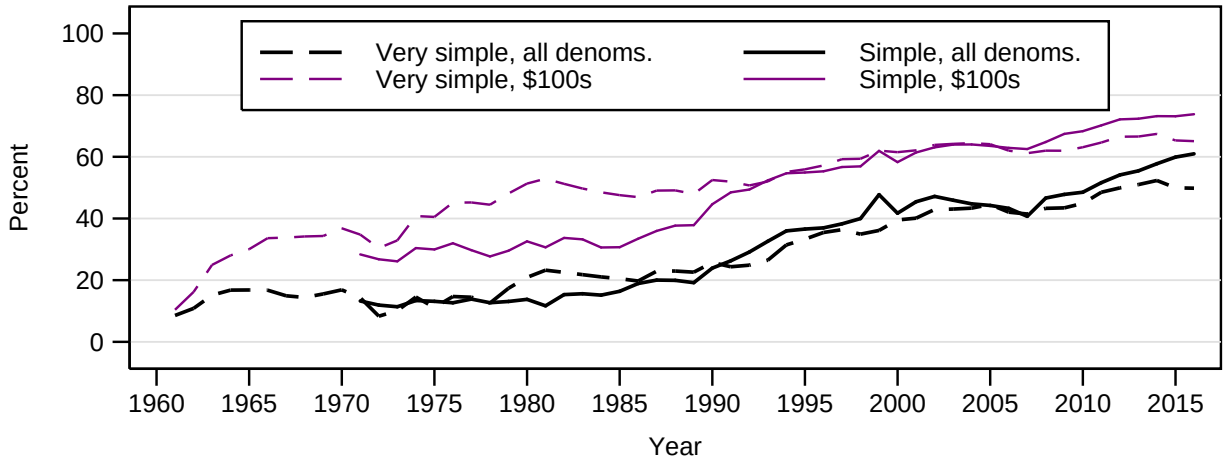


Figure 6B: Simple Estimates of the Value of U.S. Currency Abroad

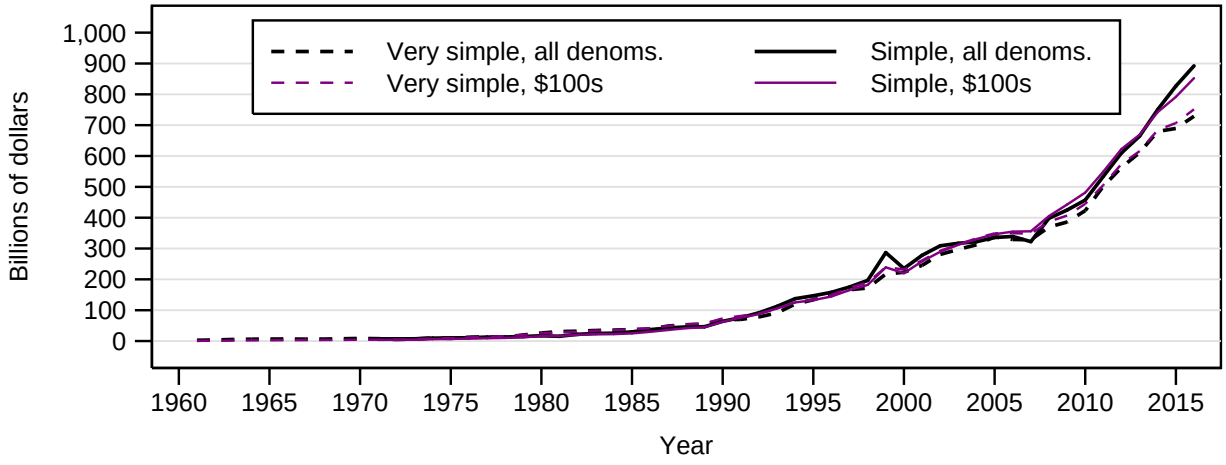


Figure 7: International Commercial Bank Shipments And Total Change in U.S. Currency Flows Abroad

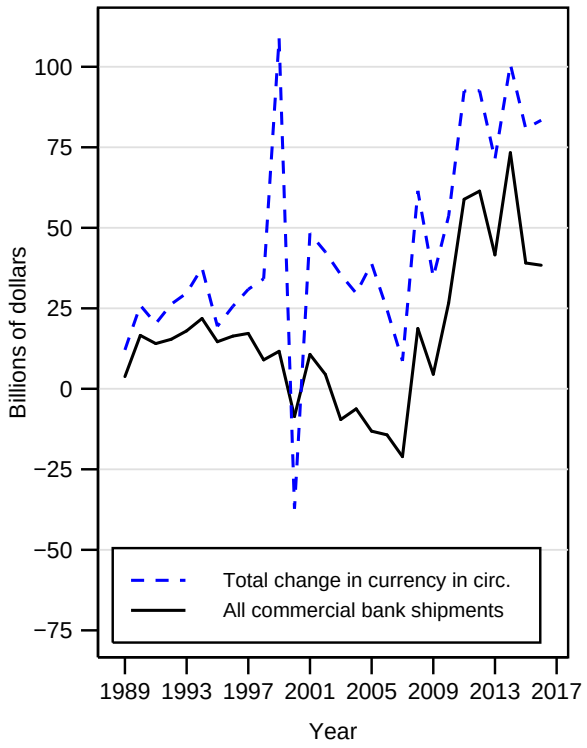


Figure 8: Total Commercial Bank Shipments and Shipments Selected Group of Countries

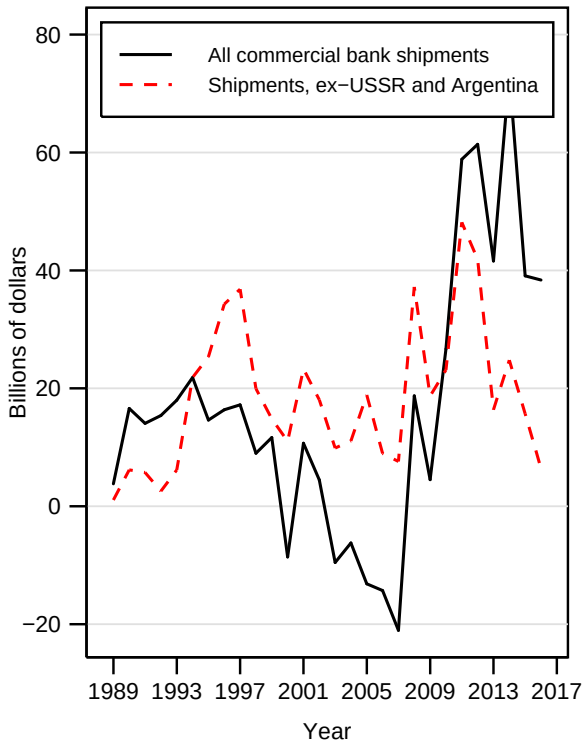


Figure 9: Total Shipments, the Shipment Proxy, And Adjusted Shipments

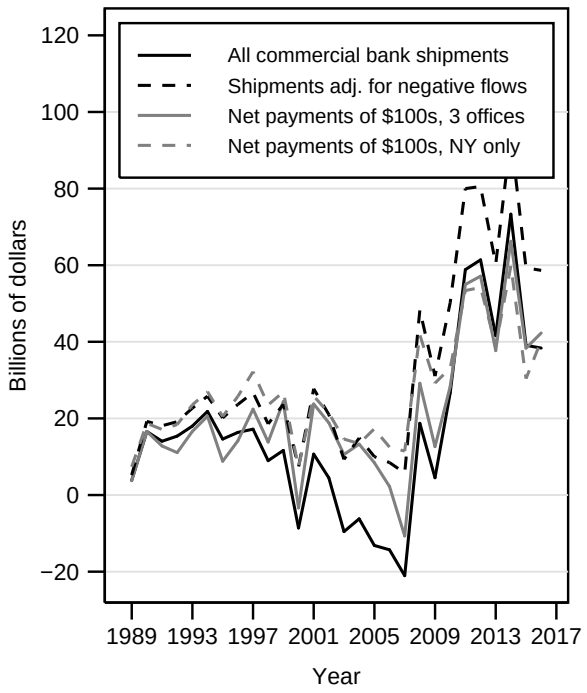
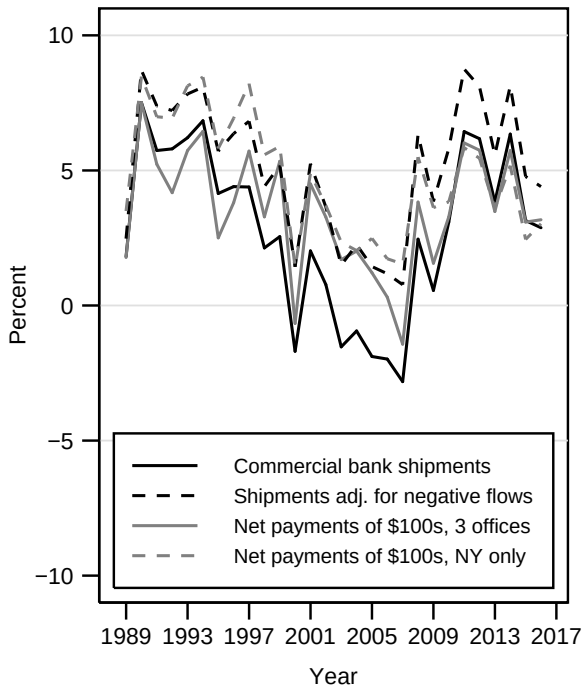


Figure 10: Flows of U.S. Currency Shipped Abroad Relative to Currency in Circulation



Note: The gray solid line in Figures 9 and 10 indicates net payments of $100s from NY, LA, and Miami.

Note: Annual totals divided by currency in circulation at end of previous year.

Figure 11A: Measures of Cumulative Flows of
U.S. Currency Abroad, 1989−2016

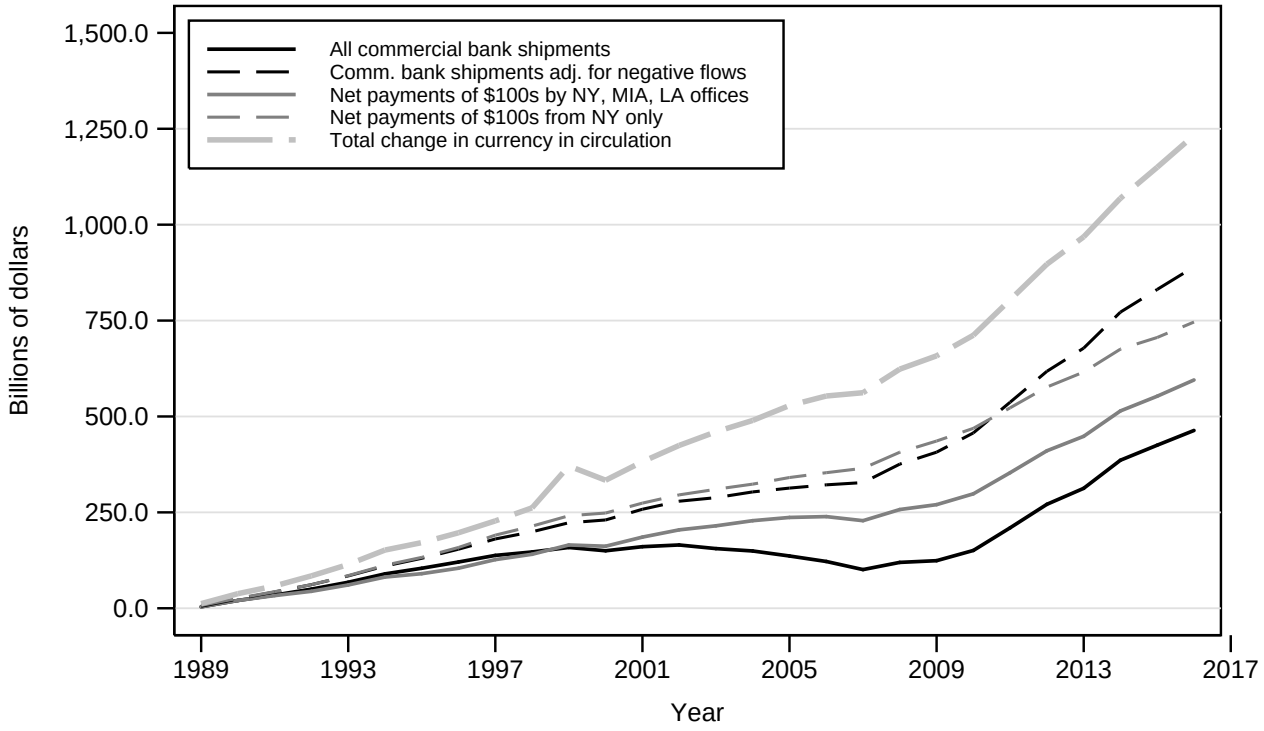


Figure 11B: Cumulative Flows of U.S. Currency Shipped Abroad
Relative to Cumulative Changes in Currency in Circulation, 1989−2016

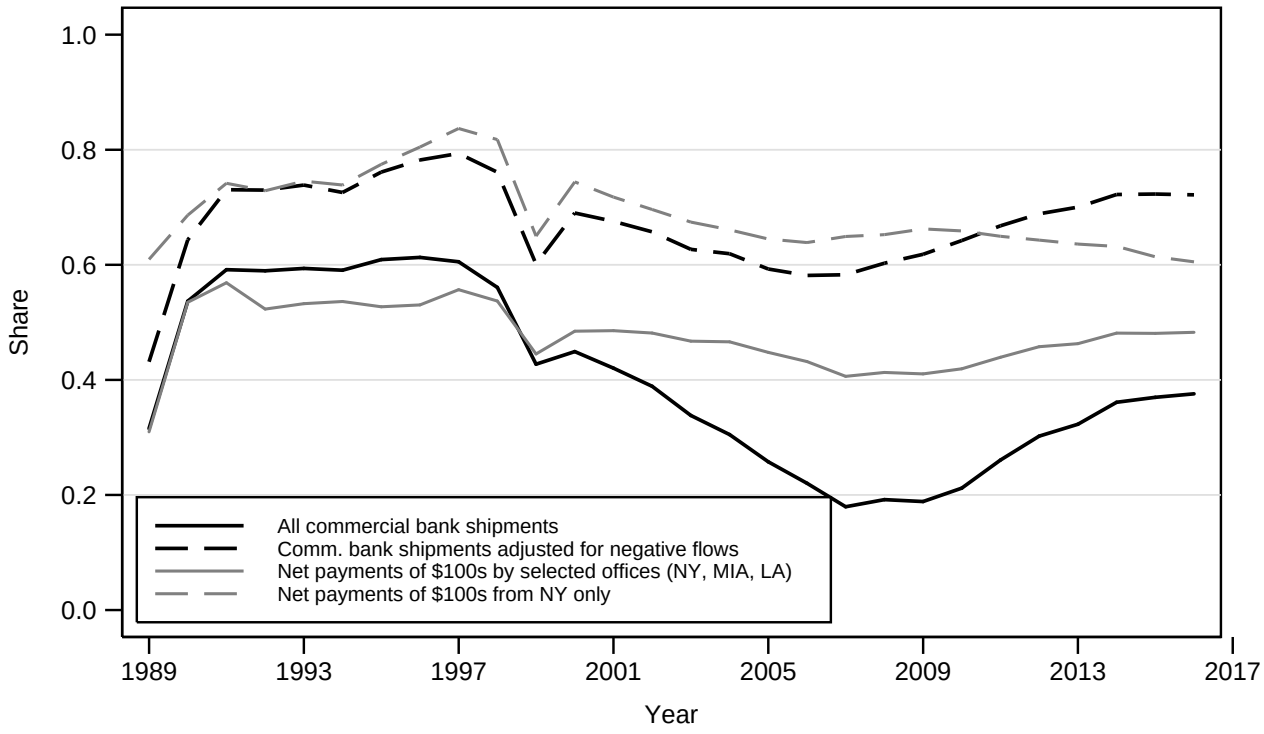


Figure 12A: X−12 Seasonal Factor Estimates
Total U.S. Currency in Circulation

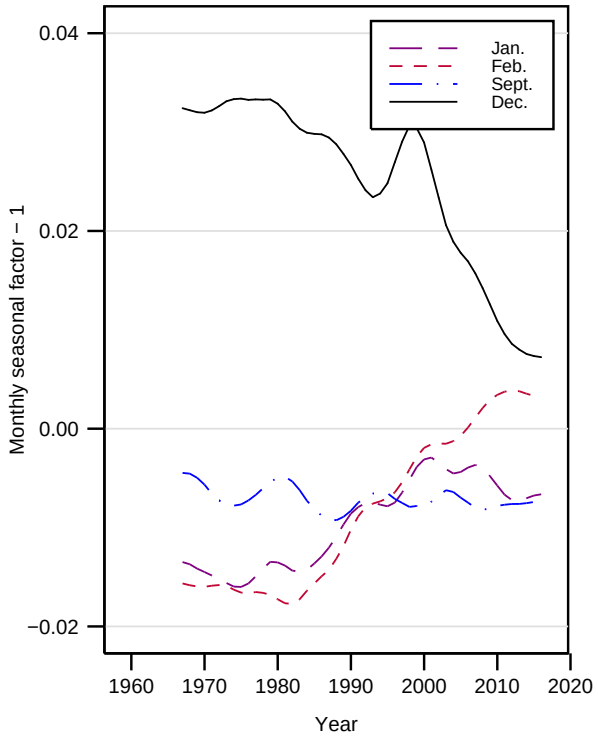


Figure 12B: X−12 Seasonal Factor Estimates
Total Canadian Currency in Circulation

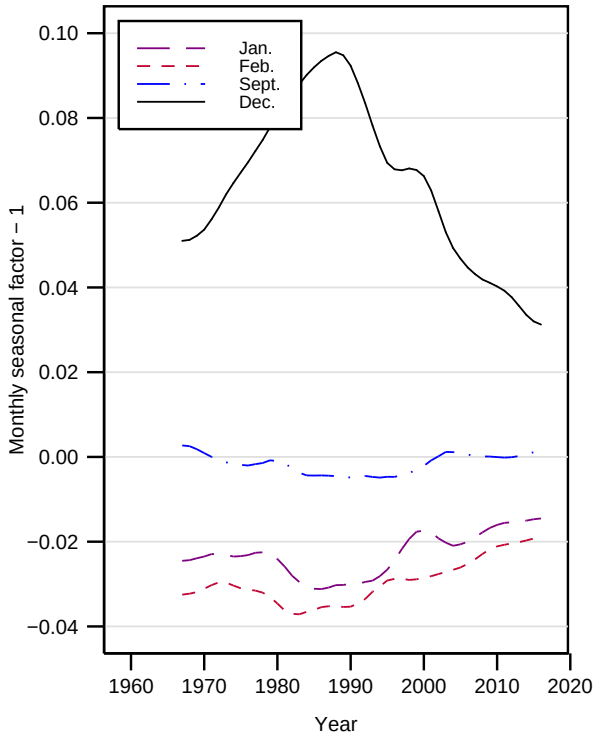


Figure 13A: Seasonal Method
Estimated Share of All U.S. Currency Abroad

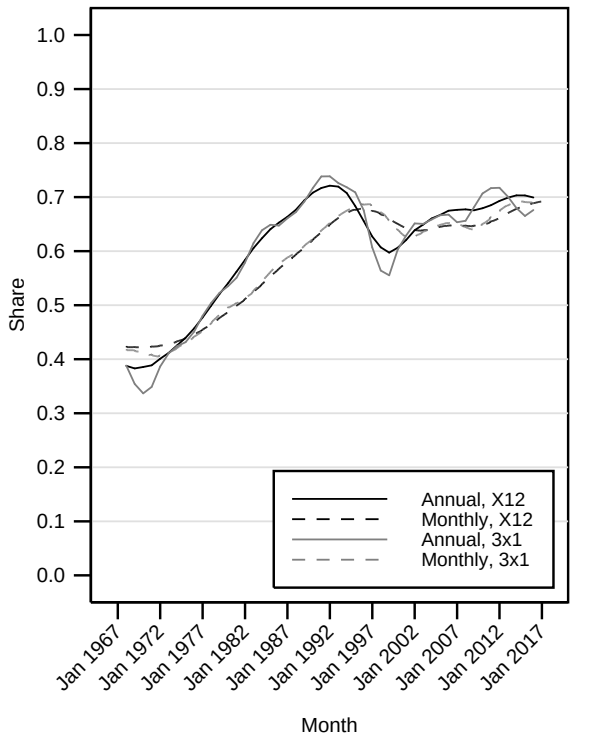


Figure 13B: Seasonal Method
Estimated Share of U.S. $100s Abroad

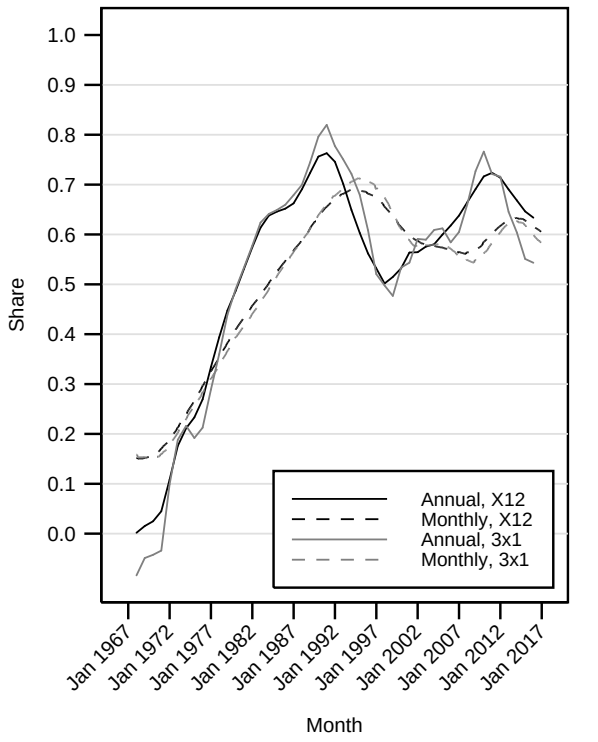


Figure 14A: Growth of Currency, Nominal GDP, and Proxy for Foreign Demand, 1988−2016

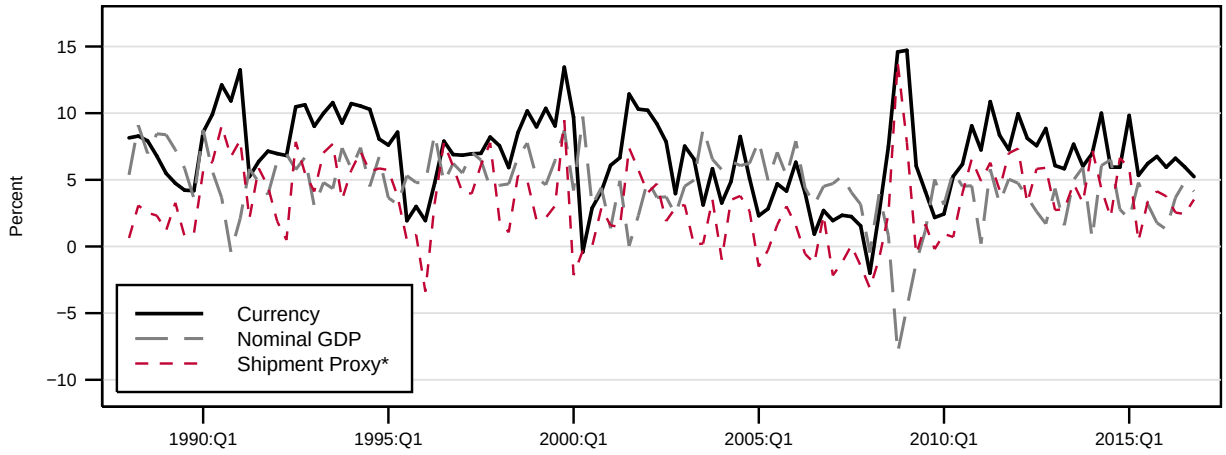


Figure 14B: Estimated Foreign and Domestic Contributions to Currency Increases, 1988−2016

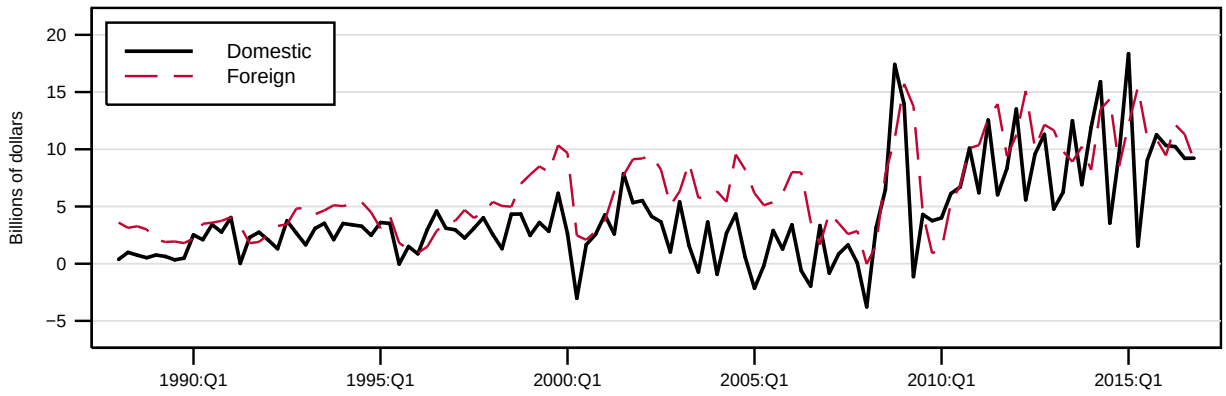
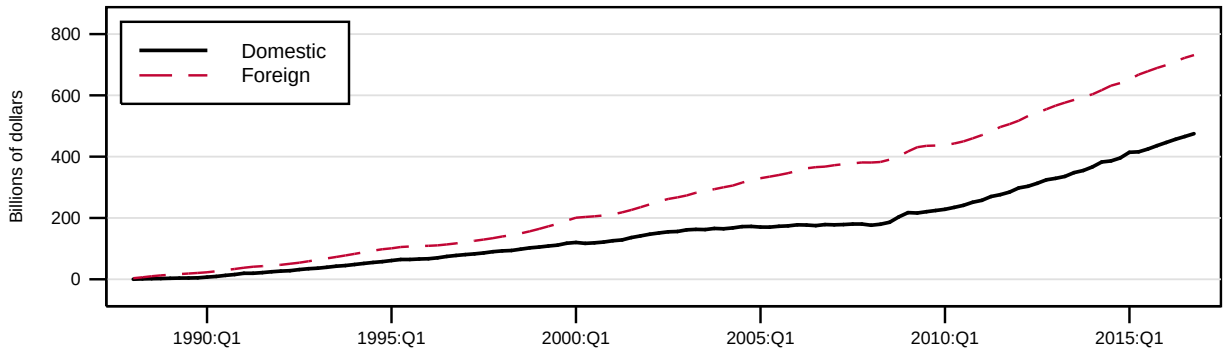


Figure 14C: Estimated Cumulative Contributions of Domestic and Foreign Factors to U.S. Currency Increases, 1988 − 2016



*Foreign proxy is commercial bank shipments adjusted for negative net shipments as described in the text divided by currency stock at the end of the previous period.
In Figure 14C, residual assigned equally to domestic and foreign factors.

Figure 15: Ratio of Currency to GDP by Denomination

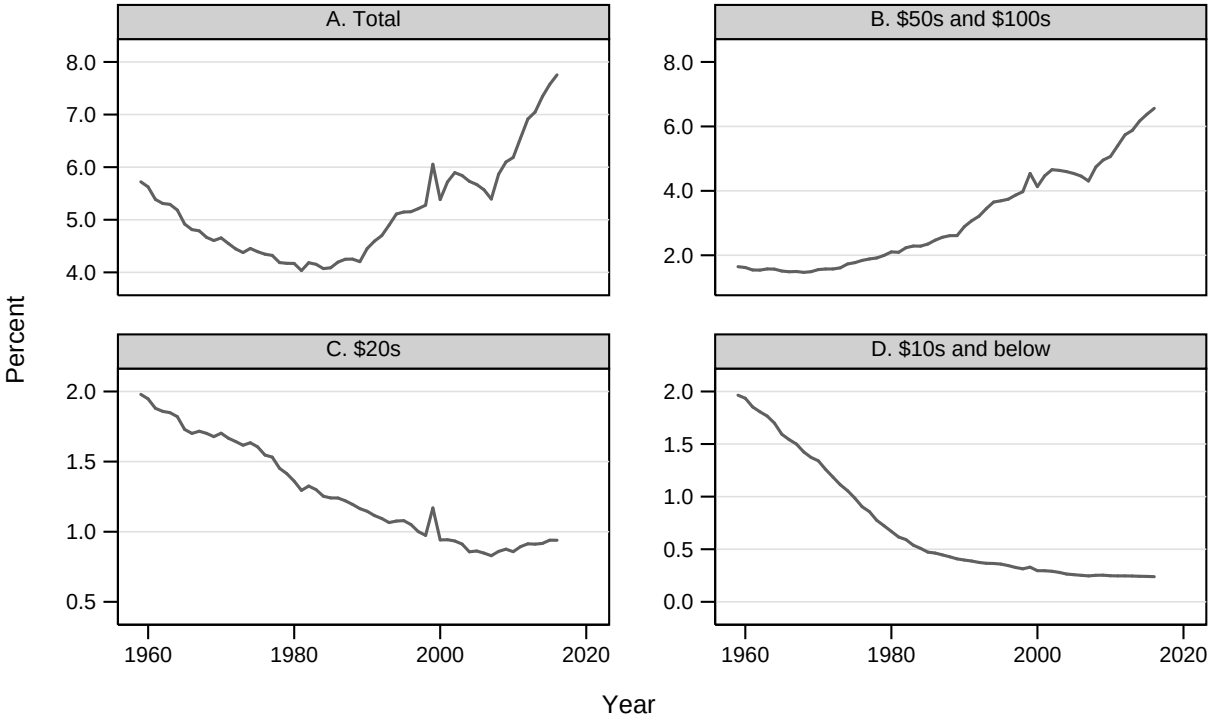
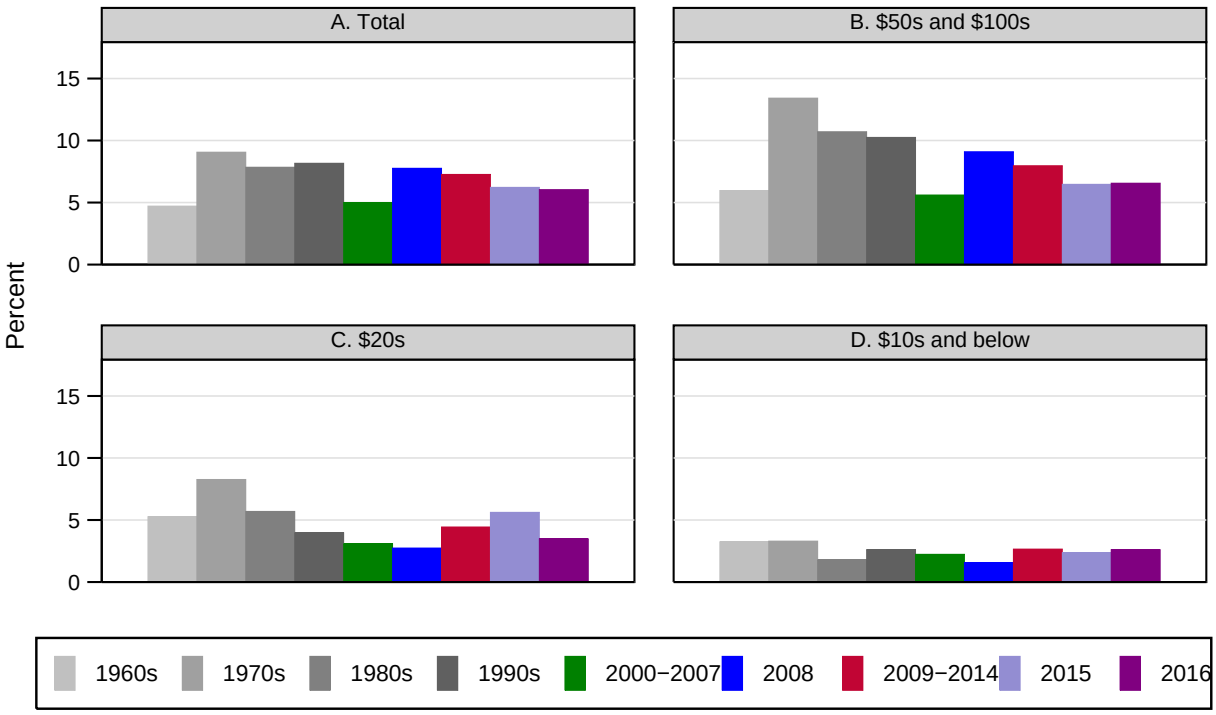


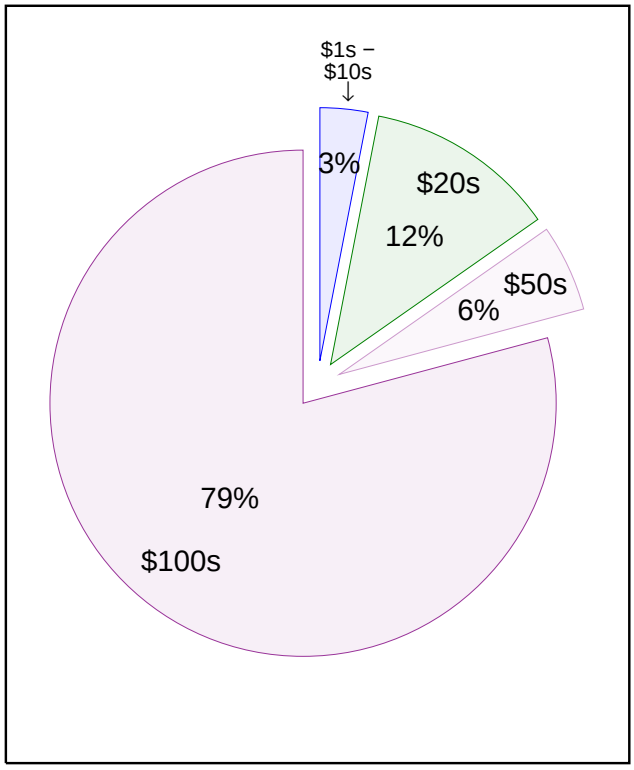
Figure 16: Average Annual Growth in Currency in Circulation by Denomination



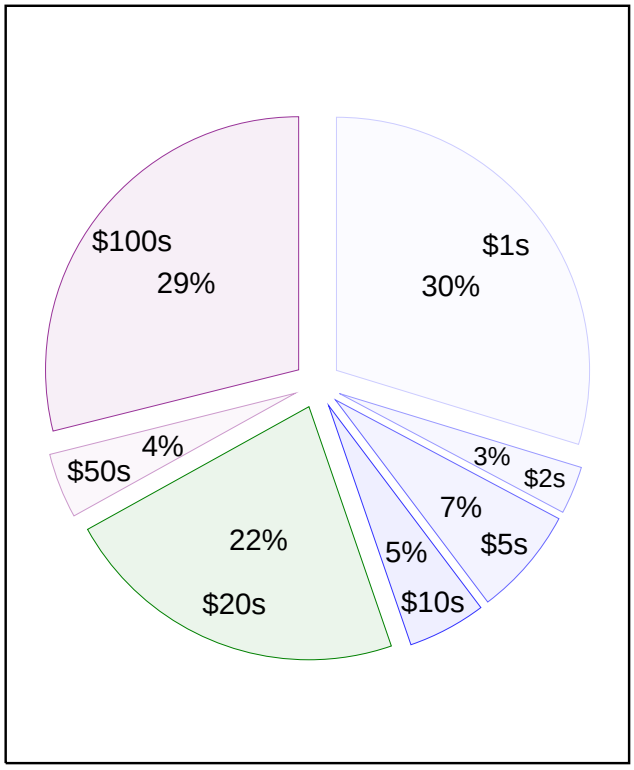
Source. U.S. Treasury

Appendix Figure 1: Shares of U.S. and Canadian Currency in Circulation
By Value and Pieces
2012 Average

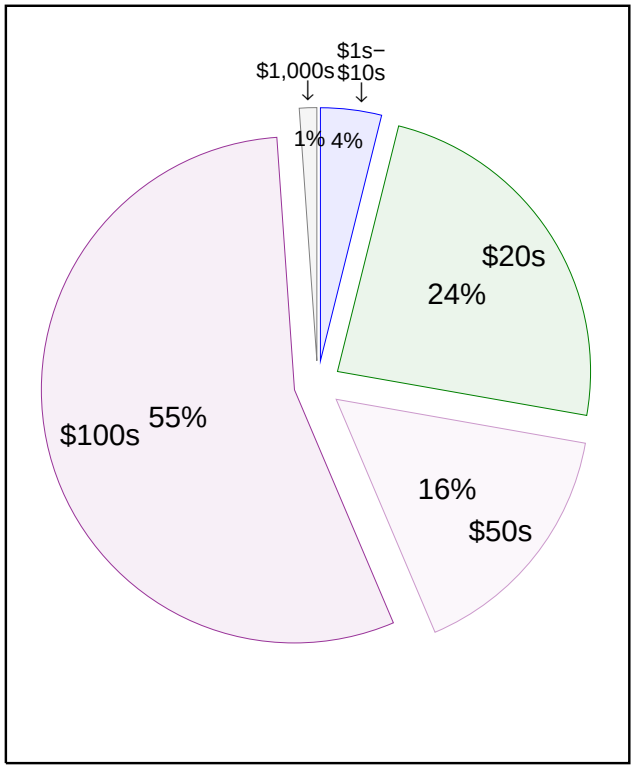
U.S. Shares, by Value



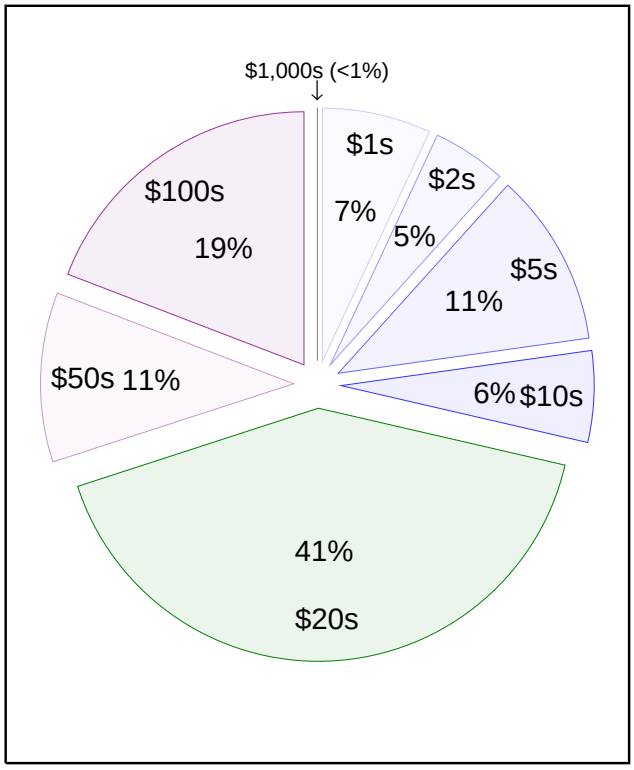
U.S. Shares, Pieces



Canadian Shares, by Value

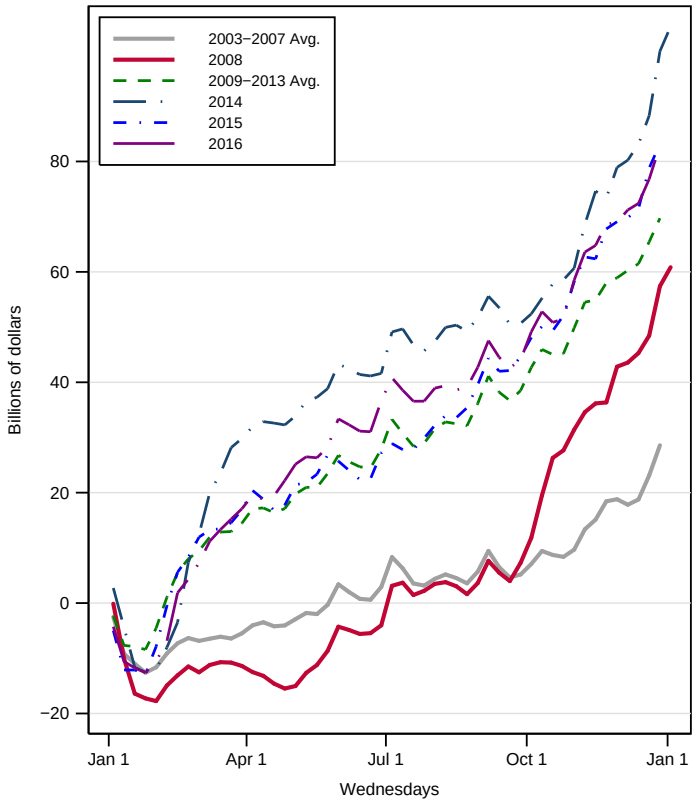


Canadian Shares, Pieces



Appendix Figure 2A: Cumulative Change in Currency in Circulation

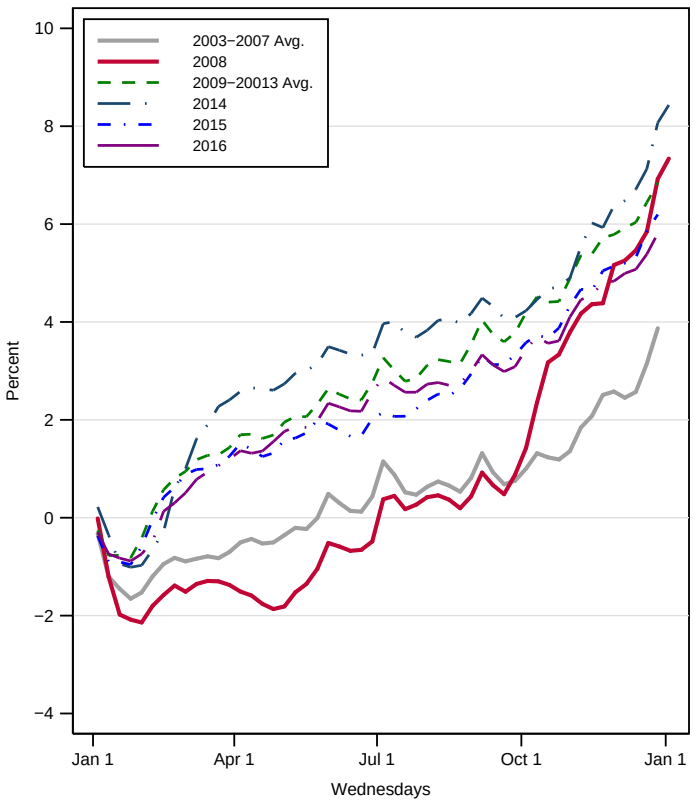
Dollar Value



Source. H.4.1 Statistical Release

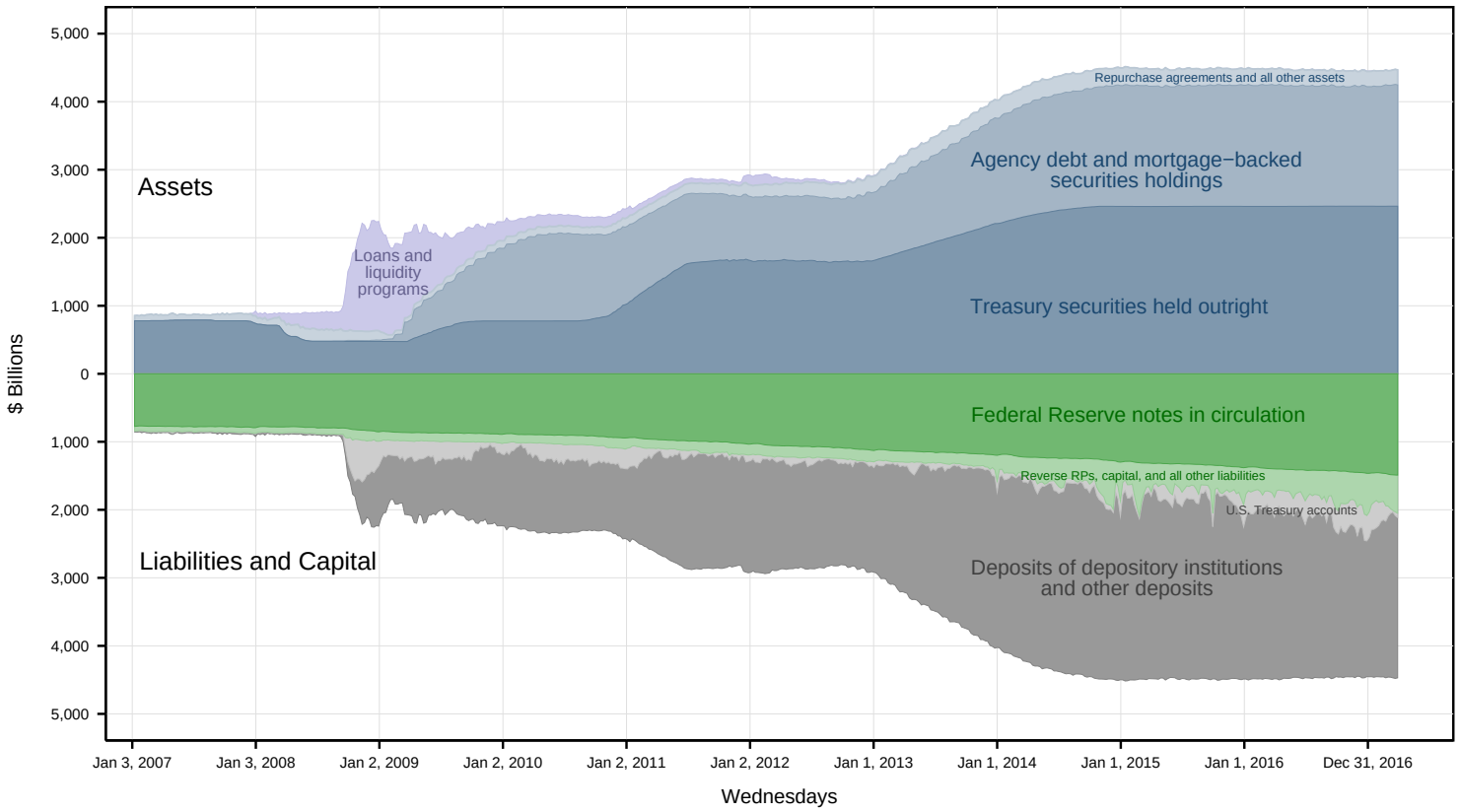
Appendix Figure 2B: Cumulative Change in Currency in Circulation

Growth Rate Terms



Source. H.4.1 Statistical Release.
Cumulative totals divided by value for last Wednesday of prior year.

Appendix Figure 3: Federal Reserve Bank Assets and Liabilities and Capital, 2007 − 2017



Source: H.4.1 Statistical Release (http://www.federalreserve.gov/releases/h41/).