The Location of U.S. Currency: How Much Is Abroad?

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Federal Reserve bank notes are widely used outside the United States. Knowing how much U.S. currency is abroad is important for a variety of reasons, but currency movements are notoriously difficult to measure, and estimates of the foreign component of currency stocks and flows have been subject to a great deal of speculation and uncertainty. Here we bring together several new methods and data sources to narrow the range of that uncertainty. According to our estimates, about $200 billion to $250 billion of U.S. currency was abroad at the end of 1995, or more than half the roughly $375 billion then in circulation outside of banks. Moreover, that proportion has been rising. Our calculations indicate that growth in foreign demand for U.S. currency—especially for hundred-dollar bills ($100s)—is far stronger than growth in U.S. demand. On average over the 1990s, the overseas stock has been growing at about three times the rate of growth of the domestic stock.

Today, foreigners hold U.S. currency for the same reasons that people once held gold coins: as a unit of account, a medium of exchange, and a store of value when the purchasing power of the domestic currency is uncertain or when other assets lack sufficient anonymity, portability, divisibility, liquidity, or security. A safe asset in an unpredictable world, dollars often flow into a country during periods of economic and political upheaval and sometimes remain there well after the crisis has subsided.

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Currency movements are difficult to measure for some of the same reasons that currency is popular: It can be easily concealed and readily carried across borders, even in large quantities (a briefcase can hold $1 million in $100s). The total amount of U.S. currency in circulation is known; in principle, one could conduct a census to determine the domestic stock and assume that the rest of the currency is abroad. However, such a census would be invasive, prohibitively costly, and unlikely to yield reliable results. Thus, the amount of currency held abroad can only be estimated, and then only from incomplete or indirect evidence about dollars flowing across U.S. borders.

Policymakers would find it useful to have a clear idea of how much U.S. currency is circulating outside the country. First, foreign demand for U.S. currency, if large and unrelated to domestic U.S. spending, will complicate the interpretation of movements in the amount of currency outstanding and in various other monetary aggregates.

Second, estimates of changes in foreign holdings of U.S. currency may also reduce the average size of the errors-and-omissions category in the U.S. international transaction accounts, which do not currently incorporate any estimates of changes in foreign holdings of currency.

Third, a significant foreign demand for U.S. currency will have important effects on the amount of seigniorage that the United States can expect.[1] All U.S. currency, including that held externally, can be thought of as a form of interest-free Treasury borrowing and therefore as a saving to the taxpayer. If the amount of currency abroad is around $200 billion, and the three-month Treasury bill rate is 5.2 percent (which it is as of this writing), the amount of seigniorage (and taxpayer saving) from externally circulating currency, calculated as the product of these two figures, would be more than $10 billion per year. Knowing more accurately the amount of seigniorage

1. Seigniorage is defined as the government's gain from converting valuable metal into more valuable coins. We use the term here in the looser sense that includes the central bank's income from issuing paper currency.

derived from externally circulating currency would assist policymakers in deciding how many resources to devote to protecting it by, for example, combating the counterfeiting of U.S. currency abroad or improving the physical quality of externally circulating notes. Add to these reasons the fact that currency outstanding has surged over recent years, and a reliable answer to the question of how much is abroad becomes a matter of considerable interest.

In all, we have examined ten methods for estimating the amount of currency held abroad. We first outline the major sources of foreign demand for U.S. currency. We also review the available information, from statistical reports to institutional structure, none of which, alone, covers the full extent of currency stocks or flows but which nonetheless point to foreign use as the major source of recent growth in U.S. currency. We then describe two of the ten methods we use to estimate the stock of currency abroad, the seasonal method and the biometric method, which provide convenient illustrations of the assumptions and empirical relationships required to estimate overseas currency flows and stocks.

After briefly summarizing the remaining eight methods, we present a summary measure, the ''median flow estimate,'' based on several methods for which we have sufficient time-series data. We show that although year-to-year changes in domestic holdings have been relatively stable, changes in total currency have grown and have become increasingly dominated by foreign movements. In light of the evidence, we examine and find unpersuasive several arguments supporting the claim that very little currency is held outside the United States. Finally, when our estimate of U.S. currency held abroad is subtracted from the total outstanding, the amount of domestically circulating currency per U.S. resident that remains is considerably smaller than the corresponding measure for most other developed countries, and we examine some of the economic forces underlying these cross-country differences.[2]

The International Market for U.S. Currency

Before the advent of paper currency, gold coin—in the form of Dutch guilders, Spanish pieces of eight, and other coins of the realm—circulated far outside the countries in which they were minted; similarly, bank notes (that is, notes issued by private commercial banks) in the United States and England in the 19th century circulated far beyond the market areas of those banks. U.S. currency today provides many of the monetary services that gold coins once did. As the leading international currency, Federal Reserve notes enter other national economies for reasons both public and private. Some countries, including Panama and Liberia, have elected at times to use the U.S. dollar as their currency. Other countries that issue currency maintain stable exchange rates between their own currency and the U.S. dollar; in the Caribbean, for example, that stability allows tourists and residents to use both dollars and local currency without fear of a sudden change in exchange value. Workers employed outside their home countries are often paid in U.S. dollars, which make their way into local economies directly or via remittances: U.S. soldiers have been paid in dollars since World War II, and many expatriate workers in the oil-producing countries of the Middle East are paid in dollars. The dollar is also the preferred currency for exchange: Travelers heading for points outside of Western Europe often economize on exchange costs by carrying dollars.

2. For earlier estimates of the foreign component of currency stocks and flows and related issues, see, for example,

Robert B. Avery, Gregory E. Elliehausen, Arthur B. Kennickell, and Paul A. Spindt, ''Changes in the Use of Transaction Accounts and Cash from 1984 to 1986,'' *Federal Reserve Bulletin,* vol. 73 (March 1987), pp. 179–96.

Alan S. Blinder, ''The Role of the Dollar as an International Currency,'' *Eastern Economic Journal,* vol. 22 (Spring 1996), pp. 127–36.

Edgar L. Feige, ''Overseas Holdings of U.S. Currency and the Underground Economy,'' in Susan Pozo, ed., *Exploring The Underground Economy: Studies of Illegal and Unreported Activity* (Kalamazoo, Mich.: W.E. Upjohn Institute for Employment Research, 1996), pp. 5–62.

Jeffrey A. Frankel, ''Still the Lingua Franca,'' *Foreign Affairs,* vol. 74 (July/August 1995), pp. 9–16.

Lawrence B. Lindsey, ''America's Most Ignored Export,'' *Durell Journal of Money and Banking,* vol. 6 (Winter 1994–95), pp. 2–5.

John Mueller, ''Most of Our Money Is Missing—Again,'' *Durell Journal of Money and Banking,* vol. 6 (Winter 1994–95), pp. 6–13.

Richard D. Porter, ''Estimates of Foreign Holdings of U.S. Currency—An Approach Based on Relative Cross-Country Seasonal Variations,'' in *Nominal Income Targeting with the Monetary Base as Instrument: An Evaluation of McCallums' Rule,* Finance and Economics Discussion Series Working Study 1 (Board of Governors of the Federal Reserve System, March 1993).

_____, ''Foreign Holdings of U.S. Currency,'' *International Economic Insights* (November/December 1993), p. 5.

_____ and Ruth A. Judson, ''The Location of U.S. Currency: How Much Is Abroad?'' (Board of Governors of the Federal Reserve System, April 15, 1996).

Franz Seitz, ''The Circulation of Deutsche Mark Abroad,'' Discussion Paper 1/95, Economic Research Group of the Deutsche Bundesbank (May 1995).

Case M. Sprenkle, ''The Case of the Missing Currency,'' *Journal of Economic Perspectives,* vol. 7 (Fall 1993), pp. 175–84.

Scott B. Summer, ''The Case of the Missing Currency, Correspondence,'' *Journal of Economic Perspectives,* vol. 8 (Fall 1994), pp. 201–03.

_____, ''The Transactions and Hoarding Demand for Currency,'' *Quarterly Review of Economics and Business,* vol. 30 (Spring 1990), pp. 75–89.

Episodes of economic and political turmoil have frequently been the catalyst for major influxes of dollars into a region. Recently, Argentina and the former Soviet Union received large inflows of dollars. In Argentina, which experienced chronic high inflation from the 1960s to the early 1990s and brief bouts of hyperinflation in the mid 1970s and late 1980s, U.S. currency is still used as the settlement medium for large-scale transactions such as those involving real estate and cars.[3] Argentina has received as much as $40 billion in net shipments of U.S. currency, or well over $1,000 per capita.[4] However, a Federal Reserve and Treasury study of the use of U.S. currency in Argentina suggests that some currency that was initially shipped to Argentina could have subsequently moved to neighboring countries.[5]

In the countries of the former Soviet Union, past and current high inflation, confiscatory currency reforms, and the underdevelopment of the banking system encourage people to hold and use U.S. dollars for everything from retail purchases of imported consumer products to the settlement of debts between and within countries. Cumulative net shipments of U.S. dollars to this part of the world have likely surpassed those to Argentina, with some estimates as high as $60 billion. Moreover, evidence from Argentina and other countries indicates that long after crisis episodes have passed, many residents continue to hold dollars as an instantly liquid form of insurance against further political or economic upheaval. Finally, in a high-inflation economy, holding dollars as currency and bearing the implicit interest cost can be more convenient than holding other available savings or transactions instruments, even if they earn interest.[6]

Data Sources for Estimates of Currency Held Abroad

We have two direct sources of information about currency *flows* abroad—the U.S. Customs Service and the Federal Reserve Bank of New York. However, data from these sources are often inadequate for measuring the *stock* of currency abroad, in particular because they miss much of the cash that is hand-carried or remitted by mail by guest workers and travelers. Thus, to better estimate stocks, we also use sources of indirect information about currency flows. We first describe the major sources of direct and indirect data on currency flows in and out of the United States. We then present other institutional and general information on currency growth and economic activity that point to a large and increasing presence of U.S. currency outside the country.

The Currency and Monetary Instrument Reports

The most obvious direct source of information on currency flows across U.S. borders are the Currency and Monetary Instrument Reports (CMIRs) required by the U.S. Customs Service.[7] In principle, these reports are a rich source of information because individuals or firms making almost any shipment of more than $10,000 in cash across a U.S. border are required to file a CMIR (the reporting threshold was raised, from $5,000 to $10,000, in 1980). Although CMIR data on shipments by banks seem to agree with the banks' own reports to the Federal Reserve Bank of

3. Daniel Heymann and Axel Leijonhufvud discuss the forces affecting currency holdings in countries experiencing high inflation but not hyperinflation (*High Inflation: The Arne Ryde Memorial Lectures*, Clarendon Press, 1995). See also Carlos A. Végh, "Stopping High Inflation," International Monetary Fund, *Staff Papers*, vol. 39 (September, 1992), pp. 626–95; and Miguel A. Savastano, "Dollarization in Latin America: Recent Evidence and Some Policy Issues," in P.D. Mizen and E.J. Pentecost, eds., *The Macroeconomics of International Currencies: Theory, Policy, and Evidence* (Brookfield, Vt.: Elgar, forthcoming).

For a perspective on this phenomenon and its relationship to sovereignty, see Benjamin J. Cohen, "The Political Economy of Currency Regions," in Edward D. Mansfield and Helen V. Milner, eds., *The Political Economy of Regionalism* (Columbia University Press, forthcoming). For an international treatment of this issue, including a discussion of the implications for balance-of-payments statistics, see John Wilson, "Physical Currency Movements and Capital Flows," in *Report on the Measurement of International Capital Flows: Part II—Background Papers* (International Monetary Fund, 1992), pp. 91–97; and Russell Krueger and Jiming Ha, "Measurement of Co-Circulation of Currencies," Working Paper 95/34 (International Monetary Fund, 1995).

4. This figure extends through 1995 the cumulation of net currency shipments to Argentina calculated in Steven Kamin and Neil R. Ericsson, "Dollarization in Argentina," International Finance Discussion Papers 460 (Board of Governors of the Federal Reserve System, 1993). Kamin and Ericsson find their estimate of Argentine dollar holdings to be consistent with the reduction in domestic money demand attributable to high inflation.

5. Graciela Kaminsky, "Study by the U.S. Treasury Department and Federal Reserve System of the Use of U.S. Currency Outside the United States" (Board of Governors of the Federal Reserve System, 1994).

6. In fact, some evidence indicates that the private holding of dollars in high-inflation regimes may possibly be more efficient than other arrangements: A recent study of the welfare cost of inflation presents evidence that the financial sectors in high-inflation countries are larger than they would be otherwise; but among such high-inflation economies, those that have been "dollarized" tend to have somewhat smaller financial sectors than the others. See William B. English, "Inflation and Financial Sector Size," Finance and Economics Discussion Series 96–16 (Board of Governors of the Federal Reserve System, April 1996).

7. For more detail on these reports, see Feige, "Overseas Holdings of U.S. Currency."

New York, the CMIR data on nonbank shipments sum to improbably large net inflows.[8] At least four factors indicate that CMIRs are neither accurate nor thorough measures of large cash shipments that take place outside the banking sector.

First, because arriving travelers must pass through Customs but departing travelers ordinarily do not, the CMIR data are biased toward measuring inflows of currency. Departing travelers are occasionally informed of the filing requirement or are targeted for enforcement purposes, but their responses are not adjusted statistically to account for the large proportion of outgoing travelers who should, but apparently do not, file CMIRs. For example, in 1994 the number of travelers entering the United States from anywhere in the world was about the same as the number of travelers leaving (about 45 million), but in that year, about 170,000 arriving travelers filed CMIRs, whereas only about 34,000 departing travelers did so.

Second, CMIRs do not capture shipments of $10,000 or less, activity that could cumulate to a significant total. In 1994, excluding travel to Mexico and Canada, 18.7 million U.S. residents left the United States, and 19.2 million visitors entered. If these travelers carried an average of $1,000 each, the unrecorded flows in each direction would be relatively large, around one-half of the measured $32.8 billion 1994 CMIR inflows and $39.1 billion outflows. For example, banking statistics seem to indicate that U.S. currency flows only back from the Caribbean to the United States; the currency going in the other direction, from the United States to the Caribbean, goes not through the international banking system but via the pockets of American tourists and others, and most of it presumably goes unrecorded.

Third, many shipments greater than $10,000 are likely to be misreported or not reported at all. Although banks and other firms are accustomed to filing CMIRs and probably do so fairly diligently, individuals are potentially less aware of these reports, less willing to file them, or even eager to avoid them.

Fourth, the record-keeping system for CMIRs was designed with the purpose of identifying individual transactions, not of developing accurate aggregate statistics on currency flows. In sum, CMIRs are an important source of data, but they probably do not provide accurate aggregate data because of a one-sided data collection process and the omission of some potentially large volumes of currency flows.

8. In the CMIR system, double counting may exist for some transactions; for example, a bank and a commercial shipper may both report the same currency shipment. Further, not all cross-border consignments of cash require a CMIR. In particular, overland shipments of currency between banks and established customers do not need to be reported, nor do overland shipments between established offices of banks (31 C.F.R. 103.23, (3) and (9)).

Foreign Currency Shipments by Banks

A second direct source of currency flow data is the information provided to the Federal Reserve Bank of New York by commercial bank-note brokers, primarily large commercial banks. Currently, we have monthly data on incoming and outgoing currency shipments by country for two intervals, the interwar period (for which the country data had been published annually) and the period beginning in 1988. We focus on the recent data.[9]

Overall, the shipments data indicate that well over $100 billion in U.S. currency on net has moved overseas since the late 1980s. From 1988 through 1991, the region receiving the bulk of currency shipments was Latin America, led by Argentina, which received a little more than one-third of total net shipments from the United States to the rest of the world in this period. Since then, Europe has become the dominant destination, reflecting the turbulence in the former Soviet Union. Net U.S. currency flows to Russia alone in both 1994 and 1995 have been at least $20 billion per year, or well more than half of total net foreign shipments of U.S. currency.

On the whole, from 1988 to 1995 about half of net U.S. currency shipments abroad have gone to Europe, with the bulk of those presumably going to Russia. About 30 percent has been evenly split between the Far East and the Middle East, with the remainder going to Latin America, particularly Argentina.

Disaggregated Sources: Surveys and Federal Reserve Cash Offices

Two of the most important sources of indirect information on currency flows are recent survey results

9. The details of the data from 1988 onward are confidential. For the interwar period, see for example, "Foreign Movements of United States Currency," Federal Reserve Bank of New York, *Monthly Review of Credit and Business Conditions*, October 1, 1926, p. 6; "Shipments of American Currency To and From Europe," *Banking and Monetary Statistics: 1914–1941* (Board of Governors of the Federal Reserve System, 1943), pp. 405–07, and table 113, pp. 417–18; and "Shipments of American Currency To and From Europe," *Federal Reserve Bulletin*, vol. 18 (January 1932), pp. 7–9. Also, some annual data cover a brief period following World War II: See *Balance of Payments Statistical Supplement to Survey of Current Business* (Department of Commerce, 1958), pp. 178–79, note 3, international investment position table referencing U.S. currency abroad in 1946–56.

and data from currency processing performed at the Federal Reserve System's Cash Offices. Twice in the mid-1980s and again in May 1995 the Federal Reserve engaged the Michigan Survey Research Center to poll at least 500 households regarding their use of currency and various transaction accounts (table 1).[10] In the latest survey, average cash holdings (line 1), the percentage of currency outstanding that is accounted for by holdings of adults (line 5), and the percentage of expenditures made with cash (line 10) all had dropped significantly from the levels of the mid-1980s. Furthermore, businesses and children are not believed to hold significant amounts of currency. Hence, the declines recorded by the surveys over a period when real per capita currency was increasing sharply (see table 3) most likely point to growing demand outside the country.

The other type of indirect data, which we use in the biometric method (described below), comes from the thirty-seven Federal Reserve Cash Offices. Each of the twelve Federal Reserve Banks has at least one main Cash Office and up to five Branch Cash Offices. The Cash Offices record—by denomination and, to a limited extent, by series—all currency received, processed, destroyed, and paid out or shipped to other Cash Offices. These data do not differentiate foreign and domestic flows, but by comparing Cash Office reports on shipments of $100s and $50s with information from the surveys, we can enhance our knowledge of stocks and flows abroad. The biometric method indicates that about two-thirds of $100s and nearly half of $50s are held abroad.

10. Results from the 1980s surveys are discussed in Avery and others, "Changes in the Use of Transaction Accounts"; and Robert B. Avery, Gregory E. Elliehausen, Arthur B. Kennickell, and Paul A. Spindt, "The Use of Cash and Transaction Accounts by American Families," *Federal Reserve Bulletin,* vol. 72 (February 1986), pp. 87–108.

1. Results of three household surveys on use of cash, 1984, 1986, and 1995

Item	June 1984	June 1986	May 1995
1. Average cash holdings (dollars)[1]	148	153	100[2]
2. Cash on hand before acquisition of cash (dollars)	50	50	27
3. Cash acquired (dollars)	196	207	149[3]
4. Days between acquisitions of cash	12	16	12
5. Percentage of total currency and coin outside of depository institutions and held by adults	11	11	5
6. Percentage of cash acquired in $100s	n.a.	n.a.	23
7. Annual turnover rate of cash (cash spent divided by average cash balance)	50	49	36
8. Number of cash transactions per month	n.a.	n.a.	29
9. Monthly cash expenditures (dollars)	633	669	301
10. Percentage of total expenditures made with cash	30	34	20

NOTE. Dollar values for 1984 and 1986 have been inflated by the chain-type price index for personal consumption expenditures to make them comparable to the nominal 1995 values. All statistics are sample means.

1. Estimated as cash on hand before the acquisition of cash (line 2) plus one-half of the cash acquired (line 3).

2. Based on 458 respondents.

3. Based on 453 respondents who held positive amounts of cash. Calculating as in note 1 for the 453 respondents in lines 2 and 3 in May 1995, average cash balances were $27 + $149/2 = $101.50. The May 1995 entry in line 1 is $100 ($1.50 less) because it includes 5 additional individuals, who held no cash whatsoever. In both of the earlier surveys, all of the respondents reported that they held some cash.

n.a. Not available.

SOURCE. Federal Reserve.

Institutional Knowledge: The New York Cash Office and $100 Notes

Hundred-dollar notes are the largest denomination now issued by the Federal Reserve. Although $20s are in more common use than $100s in the United States, $100s make up 60 percent of the dollar value of all U.S. currency outstanding. Two facts about the use of $100 notes suggest that the net new demand for them is coming primarily from abroad. First, the Federal Reserve Cash Office serving the New York City region is the primary supplier of currency to foreign users, especially of $100s, and second, its shipments of $100s are unusually large relative to the size of its District, as measured by several economic variables, including regional shares of vault cash, population, income, and deposits (table 2).[11] This Cash Office, one of the two Cash Offices in the New York District (the other is in Buffalo), has accounted for 97 percent of the nationwide net issuance of $100s since 1988; for the twenty-two years of currency issuance reported in table 2, the New York City Cash Office accounted for nearly 83 percent of the net national issuance of $100s.

Given the survey data described above (table 1), the largest possible number of $100s per person in the United States is less than one-third of a single $100 bill, while for every U.S. resident about nine

11. The determination of a given District's share of nationwide currency holdings should depend on some combination of the variables in the first five columns of table 2. Because the Federal Reserve System supplies currency on demand, we need consider only the demand for currency. That demand depends on national variables such as the price level and interest rates and on regional measures such as spending and population. If the use of cash in some Districts is more intensive than in others, that propensity would be visible in variables such as vault cash. Thus, it is fair to assume that a given District's share of currency is explained by some combination of spending (for which we substitute personal income), population, vault cash, or deposits in that District.

2. District shares of nationwide characteristics of economic size and total cash issuance

Percent

Federal Reserve District	Vault cash[1]	Population[2]	Personal income[3]	Transaction deposits[1]	Savings and transaction deposits[1]	$100s issued[4]	All denominations issued[4]
Boston	5.0	5.0	6.1	4.4	4.6	4.4	10.7
New York	13.0	9.7	12.1	14.3	14.4	82.8	80.5
Philadelphia	3.6	4.6	5.1	3.3	3.6	3.0	–.7
Cleveland	6.9	6.5	5.9	6.3	6.8	4.5	13.0
Richmond	9.7	9.4	9.3	8.8	9.5	6.7	9.4
Atlanta	12.7	12.8	11.2	11.1	12.0	–15.9	–34.8
Chicago	10.6	12.3	12.4	12.6	12.4	13.8	29.0
St. Louis	4.0	5.0	4.2	5.0	4.6	3.7	3.8
Minneapolis	1.9	3.0	2.6	3.2	2.9	1.7	1.9
Kansas City	4.6	5.4	5.0	5.9	5.3	3.0	4.3
Dallas	6.4	7.4	6.4	6.9	6.3	1.2	–3.6
San Francisco	21.5	18.8	19.6	18.1	17.5	–9.1	–13.4
Total	**100**	**100**	**100**	**100**	**100**	**100**	**100**

NOTE. Because the distribution of these values changes extremely slowly, the variation in dates for which we have data introduces only a small discrepancy into the comparisons.

1. 1995:Q4.
2. 1990 census.
3. Per capita for 1989 multiplied by the 1990 population.
4. Value issued from 1974 to 1995 inclusive.

SOURCE. Authors' calculations.

$100 notes circulate somewhere in the world.[12] In sum, the basic information we have from surveys and the Federal Reserve Cash Offices about the circulation of $100 notes is consistent with relatively low dollar use domestically and high use abroad.

Aggregate Data on the Relative Growth of Currency and Related Economic Variables

Finally, basic domestic macroeconomic data corroborate our findings that recent currency growth is not driven by domestic factors. Empirically, the amount of currency outstanding typically grows in line with, or even a bit more slowly than, consumption in the United States. Indeed, this was the pattern until 1990. However, in the current decade, currency has grown about 3½ percentage points more rapidly than consumption in nominal terms and in real per capita terms (table 3).[13] Yet as the survey data show, the 1990s have been a period of declining use of cash for consumption spending within the United States. In real per capita terms, the amount of notes outstanding, other than $100s, has not changed much since the late 1950s, so the increase is almost all attributable to $100s: the stock of $100s outstanding has risen about $700 in real terms, to nearly $850, since 1959.

Other data pointing to a dominant external demand for currency are the changes in total real per capita currency holdings and the ratio of currency to M2 since 1959, which are a puzzle if one ignores foreign currency demands (chart 1). In real terms, total per capita balances for all denominations plus coin increased relatively slowly from 1959 to 1979, then jumped sharply from the early 1980s to the end of 1995. In contrast, the direction of change in the ratio of currency to M2 was generally downward until the late 1980s, a trend that reflected in part the absence of interest paid on currency and the implicit or explicit interest paid on the rest of M2.[14] Because most of M2 bears interest at the market rate and currency yields no interest, households have an incentive to economize on currency in favor of other M2 assets, so the ratio should (other things equal) tend to decrease over time. Indeed, one might have expected this decline to have accelerated somewhat as more and more of M2 bore a market rate of interest, a process that began in 1978 and was completed for the explicit interest-

12. We do not know the proportion of survey respondents who held $100s before their acquisition of cash, but we do know the maximum number of $100s they could have held from the individual data underlying table 1, line 2. Based on this maximum as well as on line 6 and the assumption that the average holding of this denomination is the initial amount plus one-half of the $100s acquired, the maximum amount of $100s held on average could not have been more than 30 percent of one note in the 1995 survey.

13. Currency in circulation is defined as currency, including coin, held outside of the Federal Reserve and the Treasury. The currency component of M1 is equal to currency in circulation less vault cash held at depository institutions. Definitive estimates on the amounts of currency that have been lost or destroyed are not available, but presumably the quantities are small (see Robert Laurent, "Currency in Circulation and the Real Value of Notes," *Journal of Money, Credit, and Banking*, vol. 16, May 1974, pp. 213–26). In this paper we use a variety of currency measures, the choice of which depends on the availability of the data needed for a given method; hence, our estimates of currency abroad do not always refer to exactly the same currency concept. The differences between the currency measures are very small, however, relative to the magnitude of the uncertainty inherent in our estimates of overseas currency holdings. To reflect that uncertainty, we round all of the reported percentage estimates to the nearest percent.

14. A similar declining pattern for this or comparable ratios holds in most other developed countries.

3. Spending and currency measures in the United States, 1959–95

Period	Mean year-end to year-end growth (percent)			Level, end of period		
	Personal consumption expenditures	Currency component of M1	$100s	Currency component of M1	$100s	Other denominations
	Nominal			Billions of dollars		
1959	. . .	. . .	. . .	28.8	5.9	24.4
1960–69	6.5	4.6	6.2	45.7	11.0	36.9
1970–79	9.9	8.3	13.4	104.8	42.0	72.0
1980–89	7.9	7.5	10.4	222.6	118.7	123.6
1990–95	5.1	8.6	11.8	372.2	241.5	159.9
	Per capita, real terms			Per capita dollars, real terms		
1959	. . .	. . .	. . .	701	144	594
1960–69	3.0	1.1	2.7	779	188	630
1970–79	2.3	.7	5.8	839	336	576
1980–89	2.1	1.7	4.6	995	531	552
1990–95	1.0	4.5	7.7	1,303	843	558

NOTE. Growth is at logarithmic rates. End-of-period values for the currency component of M1 are December averages; for denominations, December 31. Real terms calculated with the chain-type price index for personal consumption expenditures, 1992 base year.

. . . Not applicable.

SOURCE. Federal Reserve, U.S. Department of the Treasury, and authors' calculations.

bearing components of this aggregate in the mid-1980s. In any case, until the latter part of the 1980s, the downward trend in this currency ratio was interrupted only by business cycles. Thus, the large increase in the currency ratio starting at the end of the 1980s is a surprise, suggesting once more that explaining currency growth with domestic factors alone is problematic.[15]

ESTIMATION METHODS

Because data on currency flows abroad are incomplete, cumulating them does not provide a good estimate of the stock of currency held abroad. Thus, we combine the flow data with estimates from a variety of alternate methods. We have examined ten methods for estimating the share of currency abroad. We discuss in detail two methods, one based on differences in the seasonal patterns of U.S. and Canadian currency demand and one based on biometric population estimates; thereafter, we summarize the other eight methods and present the median estimate.[16] The seasonal and biometric approaches are *indirect* methods in that they do not directly use information about currency flows or currency abroad but infer them from other characteristics of currency.

The Seasonal Method

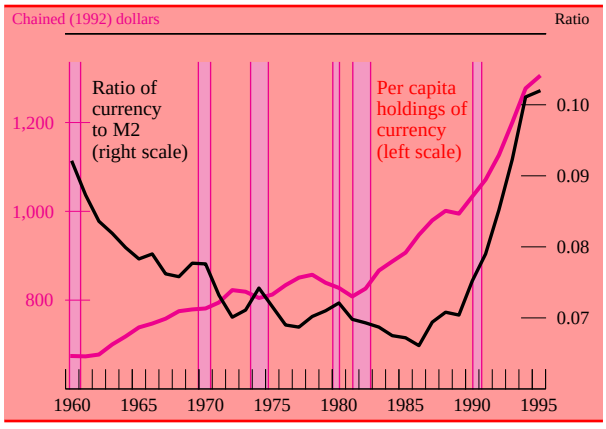
In general, the seasonal method presupposes that U.S. currency held abroad behaves differently from U.S.

15. Part of the increase in the ratio reflects the shift of assets out of M2 into non-M2 instruments such as stock and bond funds in the first few years of the 1990s; see Athanasios Orphanides and Richard Porter, "P* Revisited: Money-Based Inflation Forecasts with a Changing Equilibrium Velocity" (Board of Governors of the Federal Reserve System, 1996). But even after accounting for such shifts, the implied increase in the demand for currency from the low point of the ratio in the late 1980s would be quite large, on the order of $140 billion to account for the increase in the ratio. We will show below that a shift of this magnitude is consistent with most of the estimates of net shipments of currency abroad during the period since 1988 (table 5).

We have not included interest rates in the discussion, even though they move in the right direction to explain some of the recent acceleration in currency growth (table 3). We do not find compelling evidence that the interest sensitivity of currency is large enough to explain this acceleration (see appendix A).

16. For details of these methods, see Porter and Judson, "The Location of U.S. Currency."

1. U.S. currency ratio and the total real stock of U.S. currency measured in dollars per U.S. resident



NOTE. Currency ratio calculated with the currency component of M1 (see text note 13). Per capita holdings deflated by the chain-type price index for personal consumption expenditures, 1992 base year. Shading indicates periods of recession as defined by the National Bureau of Economic Research.

currency held at home in some measurable respect.[17] The average measured characteristic of currency, say X, will be a weighted average of the characteristic for the domestically held currency, X^d, and of that for the foreign-held currency, X^f, as follows:

$$X = \beta X^d + (1 - \beta)X^f \quad (1)$$

where the weight β is the *domestic share* of total currency outstanding, and $1 - \beta$ is the *foreign share*. By observing the overall behavior of currency, we know X. We exploit various data to infer X^d or X^f, thus allowing an estimate of the shares of currency held at home and abroad (see box "The Seasonal Variation Technique").

The seasonal method uses relative seasonal variations in the currency circulating in the United States and Canada to infer overseas holdings of dollars.[18] Four assumptions underlie this method: (1) the seasonal pattern in domestic demand for U.S. dollars is similar to the seasonal pattern of demand within Canada for Canadian dollars, (2) foreign demand for U.S. dollars has no significant seasonal pattern, (3) the circulation of Canadian dollars outside of Canada is negligible, so that the demand for Canadian dollars can be attributed solely to domestic demand, and (4) U.S. currency is not used to a substantial degree inside Canada. Under these assumptions, the share of U.S. currency abroad can be deduced by comparing the seasonality of Canadian currency in circulation to the seasonality of all U.S. currency in circulation. If foreign holdings exhibit seasonality similar to that of domestic holdings, the estimate generally provides a lower bound on the share of currency held abroad.

Seasonality in Currency Holdings and in Banking Shipments

One factor undercutting any seasonality in foreign holdings is the unpredictable timing of foreign national crises, which tend to precipitate large dollar inflows to the affected nation. In addition, transaction costs may discourage foreign users from returning to the United States those dollars received in routine exchanges that may have a seasonal pattern. If foreign currency holdings have relatively little seasonality and have tended to increase relative to domestic holdings, then overall seasonal variations in U.S.currency holdings should have diminished. Rough support for such a hypothesis comes from a comparison of the 1959–63 seasonal variations in the currency component of M1 with the component's 1991–95 variations. The seasonal fluctuations for the last five-year period are much reduced from what they were in the early period (chart 2).[19]

Canada as the Benchmark for U.S. Domestic Behavior

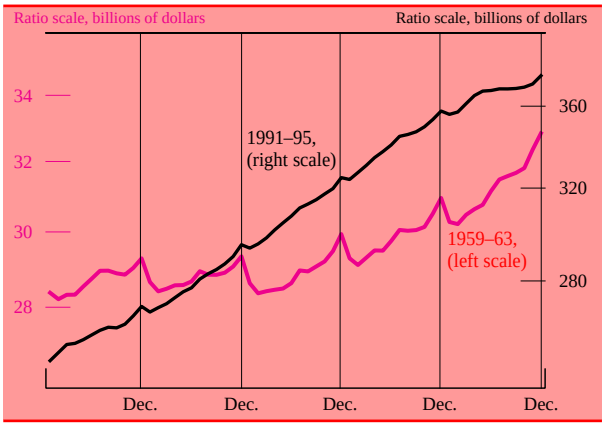
Canada is a suitable benchmark for comparison for two basic reasons. First, Canadian currency is not used outside of Canada to any significant degree. Second, because the United States and Canada have a similar set of major holidays and school vacations and share many customs, the seasonal variations in retail sales and in consumption in the two countries are similar; hence the induced domestic demand for their respective currencies should also have about the

17. Two other indirect methods, the coin and demographic, also embody this assumption (Porter and Judson, "The Location of U.S. Currency").

18. Porter and Judson, "The Location of U.S. Currency."

19. The degree of the decline may be overstated in the chart because of differing trends in the two periods. To investigate more precisely, we use a seasonal filter, STL, to extract the seasonal component of the series and focus on the seasonal amplitude, which is the difference between the maximum seasonal effect (reached in December) and the minimum (usually reached in the subsequent February). According to this measure, the amplitude of seasonal variation declines about one-half from 1960 to 1995. The STL method is set out in Robert B. Cleveland, William S. Cleveland, Jean E. McRae, and Irma Terpenning, "STL: A Seasonal-Trend Decomposition Procedure Based on Loess," Statistics Sweden, *Journal of Official Statistics*, vol. 6, no. 1 (1990), pp. 3–73. More formally, statistical tests indicate that net foreign shipments of currency by banks do not have a significant seasonal pattern; see Porter and Judson, "The Location of U.S. Currency."

2. Stock of U.S. currency in two periods, 1959–63 and 1991–95



NOTE. Currency measured as currency component of M1.

The Seasonal Variation Technique

Typically, the currency component of M1 is seasonally adjusted with a model in which the unadjusted series is viewed as a product of three terms: a trend-cycle term, a seasonal term, and an irregular, or noise, term. The seasonal term in the unadjusted series (the reciprocal of the seasonal factor) is around 1 in periods without a discernible seasonal influence; it registers its largest values above 1 in periods of significant seasonal increases of currency, which occur around Christmas and the summertime vacation period; and it is typically the furthest below 1 after such periods, when the seasonal term typically declines sharply.

Given the assumptions above, the model for the domestic and foreign holdings of currency can be written as follows. First, overall currency holdings can be modeled as the product of a trend-cycle (and irregular) component and a seasonal component in the respective (domestic and foreign) locations. In symbols let S be the seasonal term and T be the trend term so that

$$T_t S_t = T_t^d S_t^d + T_t^f S_t^f \tag{1.1}$$

where the superscript d is associated with the multiplicative currency components held domestically, the superscript f is associated with those components held outside the country, and the subscript t denotes time.[1] The left side of equation 1.1 represents the overall unadjusted currency series as the product of the trend-cycle and seasonal terms, while the right side displays a parallel decomposition for the domestic and foreign components. If we let β_t be the fraction of the overall trend held domestically, and $1 - \beta_t$ the fraction held abroad, then equation 1.1 can be rewritten as

$$T_t S_t = \beta_t T_t S_t^d + (1 - \beta_t) T_t S_t^f \tag{1.2}$$

Cancelling T_t from both sides of equation 1.2,

$$S_t = \beta_t S_t^d + (1 - \beta_t) S_t^f \tag{1.3}$$

Observe that equation 1.3 is an example of the main text's equation 1, with the seasonal term playing the role of the X variable in that definitional equation. Finally, assuming that the foreign seasonal component is always equal to 1 (that is, foreign demand does not vary seasonally), we can simplify equation 1.3 slightly:

$$S_t = \beta_t S_t^d + (1 - \beta_t) \tag{1.4}$$

Given values for the seasonal terms, equation 1.4 becomes a single equation in one unknown, β_t. We can solve for β_t provided that the seasonal terms in equation 1.4 do not equal 1. In periods without a seasonal influence (which is when $S_t = 1$ and $S_t{}^d = 1$), any value of β_t is consistent with equation 1.4, so we cannot identify a unique value. Thus, the method generates sensible estimates at an annual frequency but not at all frequencies.

The best estimate of the model is obtained by measuring the seasonal variation around Christmas, specifically from the seasonal high that is reached in currency in December to the seasonal low in February. This period of the year is the one in which the seasonal in currency is best aligned with the seasonal in transactions (retail sales).

Formally, we take equation 1.4 and rewrite the time subscript t as m,y (where m refers to the m^{th} month in the y^{th} year) and set β_t to β. Then subtracting equation 1.4 for February from equation 1.4 for the preceding December and collecting terms in β, we find that the share of currency held domestically is

$$\beta = \frac{S_{dec,y} - S_{feb,y+1}}{S^d_{dec,y} - S^d_{feb,y+1}} \tag{1.5}$$

To calculate this equation with actual values, we assume, for the reasons given above, that Canadian data can be used to estimate what the relative seasonal variations in the United States would be without any foreign holdings of currency. Given a seasonal adjustment procedure, we can use the estimate of the overall seasonal component for the currency component of M1 in the United States to estimate the numerator in equation 1.5 and use the analogous term for Canada to estimate the denominator; with the value for β, the domestic share, the share held abroad is then calculated as $1 - \beta$.

1. The irregular term in the seasonal decomposition can be viewed as being confined within the trend term. Adding an explicit irregular term does not alter the results.

same seasonal pattern.[20] This similarity implies that any difference between the seasonal variation in total demand for U.S. currency and that for Canadian currency likely reflects foreign demand for U.S. currency. In addition, Canada's set of denominations is similar to that in the United States, and the bilateral exchange rate is sufficiently close to 1 that pair-wise comparisons of individual denominations or combinations of denominations in the two currencies can be considered.

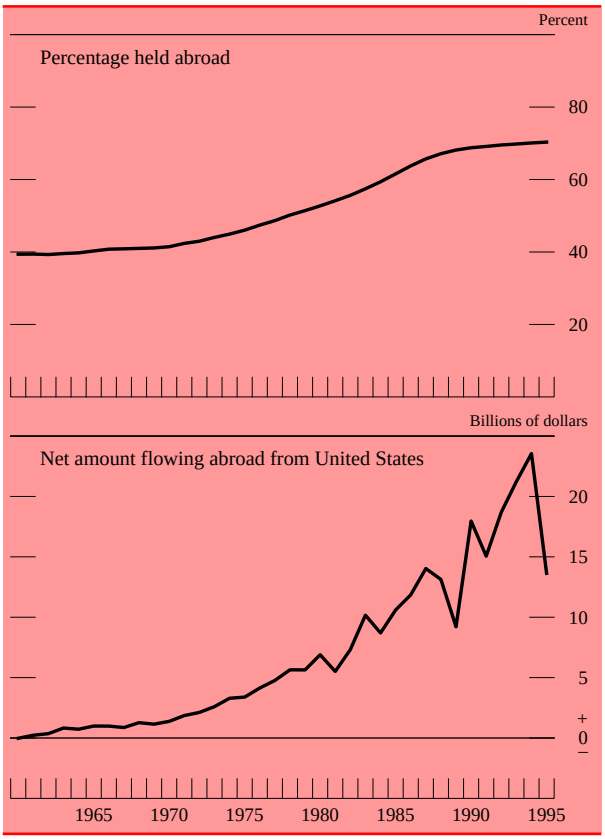
20. The notion that the seasonal term in retail sales induces the seasonal term in holdings of domestic currency is of long standing (see, for example, "Seasonal Variations in Money in Circulation," *Federal Reserve Bulletin*, vol. 18, December 1932, pp. 735–46).

Estimates from the Seasonal Method

Applying the seasonal method produces an estimate of the share of currency held abroad that begins with about 40 percent in 1960 and then rises uniformly, reaching 70 percent by 1995 (chart 3, top panel).[21] The estimated rise in the currency share abroad stems both from the drop in seasonal amplitude within the United States and from an increase in that for Canada. Toward the end of the period, the growth in the share of currency held abroad moderated, but the implied flows abroad picked up sharply (chart 3, bottom panel) because of the large increase in overall currency holdings.

21. The seasonal adjustment method, applied to the logarithm of the series, is from Cleveland and others, "STL: A Seasonal-Trend Decomposition." On balance, the results using X11 ARIMA or official (central bank) adjustment procedures are very similar to those shown here. We have chosen to report the STL results because they are the smoothest, but the basic results would be little changed if other estimates were substituted. Because the time-varying estimate is calculated without averaging, it might seem surprising that the estimate shown in the top panel of chart 3 is so smooth. By construction the STL seasonal adjustment procedure guarantees that the monthly seasonal components are smooth through time, a property that evidently carries over in this application to the ratios.

3. U.S. currency abroad, estimated with seasonal method



NOTE. Currency measured as currency component of M1.

Biometric Estimates

Our use of the biometric method focuses on the supply of $100s. The share of the nationwide net issuance of $100s attributable to four Reserve Districts—New York, Atlanta, Dallas, and San Francisco—over the past twenty-two years is out of proportion to the Districts' shares of other national economic characteristics (table 2). The anomaly regarding these four Districts is consistent with our understanding that most foreign shipments of currency go in and out of the New York District, with additional smaller net inflows through the Atlanta and Dallas Districts (from Latin America) and the San Francisco District (from the Far East).

To obtain a more precise understanding of such regional breakdowns, including the overall domestic–foreign split in currency holdings, the second estimation method we develop mimics a technique used by biologists to estimate the size of an animal population when they are able to capture only a sample of the population at any given time. The approach draws on studies by a Danish biologist, Carl Petersen, who worked more than 100 years ago. Petersen's work suggested that an animal population can be estimated by capturing a sample of animals, marking them, releasing them, and capturing another sample later.[22] Assuming that the marks do not affect the animals' ability to survive (and thus their likelihood of being in the second sample), the share of marked animals in the (unknown) general population will be the same as the share of marked animals in the recaptured sample (see box "The Biometric Method").

We adapt Petersen's approach to obtain an estimate of how much U.S. currency is abroad by combining two sources of information. First, data from Federal Reserve Cash Offices on currency shipped to and from local banks allow us to obtain virtually continuous "samples" of currency. Second, although currency is not literally marked, statistics for the pre-1990-series note are maintained separately from those for the 1990-series $100 note, which contains an embedded security thread.[23] We can think of the 1990-series notes as marked animals: When a pre-

22. E.D. Le Cren, "A Note on the History of Mark–Recapture Population Estimates," *The Journal of Animal Ecology*, vol. 34 (June 1965), pp. 453–54, notes that Petersen did not use the method for counting but that others properly credit him with the method. See C.G. Joh. Petersen, "On the Biology of Our Flat-Fishes and on the Decrease of Our Flat-Fish Fisheries," *Report of the Danish Biological Station*, vol. 4, 1893. See also G.A.F. Seber, *The Estimation of Animal Abundance and Related Parameters*, 2d ed. (Macmillan, 1982).

23. The 1990-series notes were introduced in August 1991, in $100s. The 1996-series $100 note was introduced in March 1966 (see box "The 1996-Series $100 Note").

The Biometric Method

For any geographic area, the total population of notes to be estimated, N, can be expressed in relation to three known numbers: M, the total number of marked (1990-series) notes; n, the number of notes in a sample; and m, the number of marked (1990-series) notes in a sample. Assuming that the notes circulate freely and randomly, so that the sampled proportions of marked notes are representative of the notes circulating in the area chosen, Petersen's approach (see text note 22) tells us that the sample proportion of marked notes is equal to the proportion of marked notes in the whole population:

$$\frac{M}{N} = \frac{m}{n} \tag{1.1}$$

With the total number of notes in the population, N, in some geographic area (for example, a Federal Reserve Cash Office's area) as the only unknown in this relationship, we can solve for it as

$$N = \frac{n}{m} M \tag{1.2}$$

We have used the Petersen method to obtain estimates of Federal Reserve 1990-series $100 and $50 notes circulating in the United States and abroad ($50s with the embedded security thread were introduced in 1992). We know the total number of marked notes, M, from outflows of the 1990-series $100s and $50s from each of the Federal Reserve Cash Offices; and we know the ratio of total sampled notes to marked sampled notes, n/m, from notes that are received from circulation at each Cash Office.

Because almost all currency sent to and received from foreign countries goes through the New York City Cash Office, we provisionally assume that this office is the foreign pool and the rest of the Offices together constitute the domestic pool. We estimate total notes in circulation throughout the United States excluding New York City, say N_{xny}, by applying equation 1.2 to the pool consisting of all the Offices outside New York City. Then, to obtain an estimate of total domestic currency circulation (that is, including New York City), N_d, we scale up to account for the population served by the New York City Cash Office:

$$N_d = N_{xny}\left(1 + \frac{pop_{ny}}{pop_{xny}}\right)$$

where pop_{ny} is the population served by the New York City Office, and pop_{xny} is the population served by the rest of the Cash Offices combined.

We can estimate the foreign share of currency holdings in two different ways, depending on whether total notes are determined as the sum of the notes in all the Federal Reserve Districts, say $\hat{N} = N_{ny} + N_{xny}$ (that is, an estimate) or are taken as the actual total of notes in circulation, say N. Unlike the biologists, we do know N, apart from what has been lost or destroyed.[1] Using $\hat{N}$, the estimate for total notes, the number of notes held in *foreign* countries is $N_f = \hat{N} - N_d$, and the share of notes abroad is just $N_f/\hat{N}$. This method has the advantage of using parallel estimates for domestic and foreign circulation. Using the actual N, the share of currency abroad is estimated as N_f/N, which has the advantage of using our knowledge of the total amount of currency in circulation for each of the denominations.

The range of estimates for each denomination (see table) can be considered outer bounds for the true figures because of the way they represent hoarded notes. The biometric method is able to estimate only the population of notes *actively in circulation;* the bank notes that are hoarded do not circulate and hence cannot be part of the estimates of n/m for any location. When the foreign share is estimated as the ratio of notes circulating in the foreign pool to all notes outstanding, the implicit assumption is that all uncounted notes are in the domestic pool, which is presumably not true; thus, the estimate is a lower bound of currency held abroad. Similarly, estimating the foreign share as the number of notes in the foreign pool over total measured notes implicitly assumes that notes are hoarded in the same proportion that they circulate. In this case, if notes are hoarded disproportionately abroad, the estimate could be higher; however, the estimate for $100s is about 70 percent, and we find it unlikely that more than 70 percent of the hoarded notes in the world are hoarded abroad. Thus, we consider this estimate an upper bound.[2]

1. A difference between this problem and the biometricians' is that they capture and count marked species over discrete time intervals, whereas the Federal Reserve continuously processes currency. Thus, our computations should, in principle, use a lag of the quantity of new notes in circulation to account for the fact that notes released during the sample period are not actually part of the pool for the whole period. In practice, lags do not appear to matter. For estimates of notes that are lost and destroyed, see Laurent, "Currency in Circulation."

2. The estimates appear to be relatively robust to alternative assumptions about the location of the foreign pool. Little changes if, as part of the foreign pool, we include two other cities, Los Angeles and Miami, that are believed to have significant foreign currency activity. Generally, if we try to align the District biometric estimates with the relevant economic variables that influence domestic currency location, we obtain estimates of domestic holdings that are similar to the aggregate biometric estimates.

Biometric estimates of currency held abroad

Percent

Year (December value)	$50s		$100s	
	Value used for total bank notes			
	Estimated	Actual	Estimated	Actual
1991	n.a.	n.a.	56	82
1992	29	62	47	75
1993	30	54	53	72
1994	34	48	60	71
1995	40	49	66	75

1990 note is ''sampled,'' or returned to a Federal Reserve Cash Office, it is ''marked'' by being replaced with a 1990-series note. We know how many 1990-series notes have been issued by each Federal Reserve Cash Office, and we know how many return to the Cash Offices in later samples. Second, we make use of the institutional fact that the New York City Cash Office handles relatively few cash shipments to and from domestic banks and that most of the currency shipments it handles are to and from foreign banks. Thus, if we can estimate the ''population'' of dollars in the ''pool'' served by each Federal Reserve Cash Office, the currency abroad can be estimated as the population in the New York City Cash Office pool.

Using the biometric method, we find that the December 1995 estimate of the share of $100s held abroad is between 66 percent and 75 percent and the estimate for $50s (marked with a security thread in 1992) is between 40 percent and 49 percent.[24]

Summary of All Estimation Methods

In addition to the two methods described above, eight other techniques were developed to estimate the stock of U.S. currency held abroad. These are summarized in table 4.

The estimate of the foreign share of currency using indirect estimates of the type just described is just under 30 percent using the coin method and ranges from about 50 percent to 70 percent using the biometric, demographic, and seasonal methods (table 5).

Although flow-based methods (both direct and outlier) do not yield straightforward estimates of the stock held abroad, such estimates can be derived because the flow data over the years can be consistent only with a relatively narrow range for the overseas stock. The estimates are obtainable from a trial-and-error procedure using various assumed values for the current proportion abroad.[25]

The 1996-Series $100 Note

Domestic and foreign shipments of a newly designed U.S. $100 note began in March 1996. Aside from minor changes introduced in 1990, the 1996 note was the first redesign of U.S. currency since 1928. The goal of the change was to preserve as much of the traditional appearance of the note as possible while introducing new security features that would make the note more difficult to counterfeit. With the new design, which will be applied to smaller denominations over six- to twelve-month intervals, notes are the same size, use the same ink color and paper, and feature the same historical figures and monuments as before. However, the portrait has been enlarged and moved to the left to make room for a watermark that matches the portrait. Other security features include microprinting around the portrait and elsewhere, a thread woven into the note in a different position for each denomination, and, for the larger denominations, a special ink for the denomination number in the lower right front corner of the note that changes color when one changes the viewing angle of the note.

Taking the midpoint of this range of estimates gives us a way of assigning an end-of-year value for the share abroad for any method for which we have flow data; for example, we derive an extreme range of 49 percent to 71 percent for the shipments proxy (see note 25), the midpoint of which is 60 percent.[26] Overall, the shares of currency held abroad at year-end 1995 as derived from the flow-based estimates range from the low of 17 percent for the CMIR statistics to a high of 60 percent using the shipments proxy.

We have also used the same trial-and-error method to get an estimate of currency held abroad averaging across all of the methods. We begin by taking the estimated flows abroad for each year of the period

24. As an alternative, we have also estimated the model for each Cash Office and then aggregated the results. The estimate in the text should be preferred if there are significant movements of currency (leakages) across these domestic pools. In any event, this alternative estimate tends to be within a few percentage points of those shown in the text by the end of the sample period. Thus, it does not seem to matter very much whether we explicitly consider leakages of currency across the domestic pools.

25. To see the steps involved, consider what foreign holdings of currency would be consistent with some flow estimates. According to the shipments proxy, currency shipped abroad between 1977 and 1995 totaled $183.3 billion, on net, as shown in table 5, column 1. If no currency had been held overseas at the end of 1976, the total stock of foreign holdings at the end of 1995 would have been $183.3, or 49 percent of the total outstanding. At the other extreme, if all currency outstanding at the end of 1976 had been held overseas ($80.1 billion, not seasonally adjusted), then the stock of foreign holdings would have been $263.4 billion, or 71 percent of the total.

26. Clearly, neither endpoint is likely to be correct, whereas a value near the middle is much more likely to be so. Thus, we will use the midpoint in what follows as a rough gauge of the percentage held abroad.

from 1977 to 1995 for each of the seven available methods.[27] For each year of the period, we take the median value of the seven estimates, which are then summed across years to obtain the total median flow estimate for the entire period, shown in the first two columns of the bottom row of table 5. Taking the flows from the median flow estimate and using the same technique to estimate year-end shares that we used before for each of the direct methods (taking the midpoint between the two extremes), we obtain a midpoint estimate of 55 percent as the proportion of total currency that was held abroad at the end of 1995.

As a check on this estimated percentage abroad, it is helpful to evaluate the largest denomination in active circulation, the hundred-dollar bill, which plays such a major role in the overseas currency market. The available estimates for $100s, shown in table 5, are consistent with 74 percent of this denomination being held abroad. If only $100s were abroad, they alone could account for an overseas share for total currency of 44 percent. A reasonable assumption is that the smaller denominations could easily

27. For three of the methods (biometric, demographic, and foreign currency shipments), we do not have sufficient years of data to include them in the median calculation.

4. Methods for estimating currency abroad

Method	Description
Indirect (stock-based)	
Seasonal	Described in text
Biometric	Described in text
Coin	As in the seasonal method, we use Canada's ratio of notes to coin to estimate the U.S. domestic ratio, assuming that U.S. coins are not typically used outside the country
Demographic	Estimates of the ages of domestic and foreign notes were obtained from special samples of physical notes taken in March and October 1989. The overall age of notes in circulation is a weighted average of notes circulating abroad and domestically
Direct (flow-based)	
Customs reports	Businesses and individuals moving more than $10,000 across U.S. borders must generally file Currency and Monetary Instrument Reports (CMIRs) with U.S. Customs. Incoming travelers are informed of the filing requirement on their Customs Declaration. Departing travelers are occasionally informed of the filing requirement or are targeted for enforcement purposes
Foreign currency shipments	Net foreign currency shipments are reported to Federal Reserve Cash Offices on an informal basis by the small number of commercial banks that are major international shippers of currency
Shipments proxy	We assume that monthly net shipments of $100s from the New York City Cash Office are approximately equal to net shipments abroad of all currency. We exploit the institutional fact that foreign shipments are predominantly in $100 notes and that they most often originate at the Federal Reserve Bank of New York. We assume that the three sources of disparity between actual net flows and New York shipments (that is, the quantity of $100s used domestically within the area served by the N.Y. Office, the quantity of lower-denomination notes this Office sends abroad, and foreign shipments by other Cash Offices) are all small
Cash Office flows	We compare currency shipment data from each Federal Reserve Cash Office with other indicators of regional cash demand such as population and income. Cash Offices whose share of total shipments is much different from their population or income shares are assumed to be making or receiving foreign shipments. Statistical methods yield an estimate of the domestic cash demand component as indicated by local population and income
Outlier-based (flow-based)	
Money demand	If currency holdings abroad increase sharply, then predictions of U.S. demand based on domestic factors such as U.S. interest rates and transactions should produce a significant underestimate. This approach measures the net flows of currency abroad from prediction errors generated by the Federal Reserve Board staff's currency demand model
Signal extraction	Like the money-demand method, this method is based on outliers from a prespecified relationship, in this case a time-series model
Summary measure of currency flows abroad	
Median flow estimate	Computed as the median in each year of the estimates from seven of the above methods: seasonal, coin, Customs reports, shipments proxy, Cash Office flows, money demand, and signal extraction. The remaining three methods do not have data for enough years to be included in this estimate

contribute 11 additional percentage points.[28] Thus, the evidence for $100s appears consistent with an estimated minimum of around 55 percent of currency being held abroad.

Properties of Median Flow Estimate of Overseas Currency Flows

All our methods except the CMIR indicate that overseas currency flows are large and growing. We focus on the median flow estimate because it does not depend very much on the results of any one method. The median flow calculations show that the overseas component of currency flows has been picking up, to more than 70 percent of total currency flows in the 1990s (table 6). The domestic flows show no distinct trend, and most of the year-to-year changes in the currency component of M1 (including the pickup in the 1990s) are accounted for by variations in the foreign flows.[29] (Appendix A is an economic and statistical analysis of these summary flows.)

Two notable multiyear spurts appear in the net amount of currency going abroad: in 1990 and the early part of 1991 and again in 1993 and 1994. The first surge is associated with an increase to Argentina and with a worldwide increase in the demand for dollar currency as a result of the Persian Gulf war; the second is part of the deteriorating situation in Russia and other parts of the former Soviet Union. Although overseas currency flows tended to drop back somewhat after these surges, the general upward path for foreign currency shipments is unmistakable.

Predicting the future course of shipments is even more problematic than estimating past flows. Some of the currency held abroad is used by travelers to areas outside of Western Europe, so that more such travel is likely to increases the foreign demand for currency. But the remaining, larger component is much more unpredictable and subject to massive and abrupt shifts because of wars or fundamental changes in economic and political regimes or to evolving fears about such developments.

28. Estimates from the biometric, seasonal, and demographic methods for denominations less than $100 can easily account for the needed increment.

29. Statistically, they have a simple correlation coefficient of 0.98 with annual data.

5. Net flows of U.S. currency to foreign locations and the percentage of U.S. currency abroad, by method of estimation

Method	Flow (billions of dollars)[1]		Stock, December 1995 except as noted (percent)	
	1977–95	1988–95	Overall	$100s
Indirect (stock-based) methods				
Seasonal	223.6	132.5	70	74
Biometric	n.a.	n.a.	n.a.	70[1]
Coin	173.8	92.2	29	. . .
Demographic	. . .	. . .	49[2]	51[3]
Direct (flow-based) methods				
Customs reports	5.2	42.1	17[4]	n.a.
Net foreign currency shipments, as compiled by N.Y. FR Cash Office	n.a.	107.1	54[4]	. . .
Shipments proxy	183.3	140.3	60[4]	. . .
Estimates based on Cash Office flows	163.1	123.2	55[4]	63[4]
Outlier-based (flow-based) methods				
Money demand	119.6	104.6	43[4]	. . .
Signal extraction	179.6	140.4	59[4]	94[4]
Median flow estimate[5]	**163.8**	**123.1**	**55**[4]	**74**[6]

NOTE. For detail on the results of the coin, shipments proxy, Cash Office, and outlier-based methods, see Porter and Judson, "The Location of U.S. Currency." For detail on the demographic method, see Feige, "Overseas Holdings of U.S. Currency."

1. The average of the two estimates that bound the true value.
2. Surveys taken in the spring and fall of 1989. An updated estimate of the currency held abroad based on this 1989 estimate and the median flow estimate (last row in table) yields a result of 59 percent at the end of 1995.
3. This value becomes 78 percent when updated by the increase in $100s since 1989 that is associated with the shipments proxy.
4. Midpoint of feasible range for proportion of currency held abroad; see text.
5. Computed by taking, for each year, the median of the seven methods that have data for 1977–95 and then taking the median of the resulting series.
6. Median of all methods yielding a value, with the demographic value updated as in note 3.

n.a. Not available.
. . . Not applicable.

6. Increase in the currency component of M1, by foreign or domestic destination

Billions of dollars except as noted

Year	Total increase[1]	Going to foreign economies		Going to domestic economy	
		Amount	Percent	Amount	Percent
1977	7.9	1.6	20.2	6.3	79.8
1978	8.6	2.6	29.8	6.1	70.2
1979	8.8	2.4	27.2	6.4	72.8
1980	10.6	3.6	33.7	7.0	66.3
1981	7.2	2.3	32.0	4.9	68.0
1982	9.9	3.8	38.1	6.2	61.9
1983	13.7	5.3	38.7	8.4	61.3
1984	9.9	3.5	35.6	6.4	64.4
1985	11.8	5.0	42.5	6.8	57.5
1986	12.8	4.6	36.2	8.2	63.8
1987	16.1	6.0	37.3	10.1	62.7
1988	15.4	6.5	41.9	9.0	58.1
1989	10.4	5.7	54.5	4.7	45.5
1990	24.2	18.3	75.7	5.9	24.3
1991	20.6	15.1	73.1	5.5	26.9
1992	25.5	18.1	71.2	7.3	28.8
1993	29.5	22.3	75.6	7.2	24.4
1994	32.5	23.6	72.5	8.9	27.5
1995	18.3	13.6	74.5	4.7	25.5

1. December to December, seasonally adjusted.
SOURCE. Federal Reserve and authors' calculations.

Finally, the growth of total U.S. currency outstanding over the past fifteen years has clearly outpaced both the inflation rate and the growth of the U.S. population (that is, as shown in chart 4, total real U.S. currency outstanding per U.S. resident has risen substantially since the early 1980s). But the level of real domestic balances has been nearly flat since the late 1980s (chart 4), a result, perhaps, of the increasing use of currency substitutes such as checks and credit cards (as found in the 1995 currency survey). By contrast, real foreign demand has been increasing sharply, resulting in a more stable appearance for the trend in total real currency per U.S. resident than for either of its components.[30]

The Contrarian View That Most U.S. Currency Is Held at Home

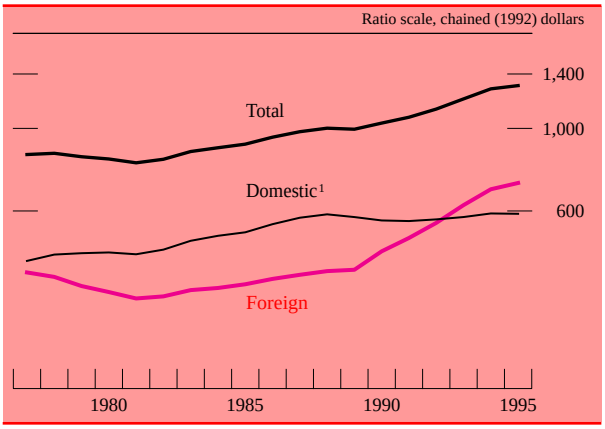
One of our basic findings is that most of the recent increase in the demand for currency has been from outside of the United States. The other possibility is that the increased demand has been domestic in origin. But domestic sources for the recent surge in total cash holdings are difficult to identify. Most analysts do not ascribe very much currency holding to businesses; the thinness of their likely holdings can be seen from simple back-of-envelope calculations.[31] And we have already seen that surveys do not assign much cash to households, although respondents may understate the true amounts they hold.[32]

An unreported rise in the use of currency could reflect a rise in tax evasion or underground activity (such behavior is very unlikely to be picked up in a survey of currency usage). But the estimated size of the unrecorded economy does not seem sufficient to account for the observed increase in currency holdings. Suppose that 10 percent of U.S. gross domestic product were generated in the cash economy—a generous assumption—and that all worldwide illegal drug transactions were exclusively done with U.S. currency (an assumption that double counts the illegal drug transactions included in the U.S. cash economy). We know from currency surveys that an average unit of currency turns over on the order of thirty-five to fifty times per year. Thus, the amount of currency required to support both the 10 percent of our $7 trillion GDP economy plus all drug trafficking (reported to be on the order of $300 billion) would be between about $20 billion and $30 billion, or only 5 percent to 8 percent of U.S. currency outstanding.[33]

Tax avoidance is the most likely other possibility that would account for the cash we attribute to foreign holdings. Suppose that, to avoid taxation, individuals and businesses manage to hide sizable

30. The foreign component is the median flow estimate for 1977–95, here deflated by U.S. population because we are uncertain of the size of the foreign population that holds U.S. currency. The levels for the foreign component are based on the midpoint of the range for this series, estimated to be 55 percent at the end of 1995.

4. Median flow estimate of the foreign component of the total real stock of U.S. currency, measured in dollars per U.S. resident



NOTE. Currency measured as currency component of M1 and deflated by the chain-type price index for personal consumption expenditures, 1992 base year.

1. The domestic component is defined here as total less foreign.

31. Most businesses need nothing more than seed cash to operate, and the total amount of such cash is not likely to be significant, as the following calculation shows. Almost 2.7 million retail establishments existed in 1992. Taking certain elements of cash use at supermarket chains as the standard for all retail establishments that year, assume that each establishment had ten cash registers (currently the median number for supermarket chains) and each register contained $200 of seed cash (the amount that at least one large supermarket chain uses for that purpose); then the total currency holdings by all retail establishments would have been only $5.4 billion, or 1.8 percent of the total stock of currency at the end of 1992. If, in addition, one business days' worth of total consumption was always in transit to depository institutions, the total amount from both of these sources would have been only $22.3 billion, or only 7.7 percent of total currency holdings in that year.

32. Even taken at face value, CMIR statistics contradict claims that the foreign component is small. For example, the CMIR data imply that, taking the midpoint of the range of estimates, 17 percent of currency was held abroad at the end of 1995; but in that case, the implied amount overseas at the beginning of the sample (the end of 1976) would have been 67 percent. On the other hand, if little currency is held abroad currently, how would one account for the $53.2 billion in currency that was returned to the United States in 1995, according to CMIR statistics?

33. That is, with a turnover rate of fifty, $([0.1 \times 7 \times 10^{12}] + [300 \times 10^{9}]) / 50 = 20 \times 10^{9}$. The most recent cash survey, in 1995, found that the turnover rate of currency was about thirty-six times per year, down from a rate of fifty times per year in the mid-1980s (a decline from about seven days per turnover to ten). Such a decline might be expected in light of the generally lower level of interest rates prevailing more recently.

amounts of cash that they had skimmed from their business cash receipts. Such activities undoubtedly occur, but it strikes us as dubious that in the aggregate they could fill the void, given that currency, which does not pay interest, must compete with many other investment vehicles that produce significant real returns.

Another counterargument to our findings would be that we have not given sufficient recognition to the unique characteristics of currency, including its anonymity, which can have great value in some (mostly illicit) transactions. However, this advantage is not unique to transactions within the United States but extends to the world, in part because of even fewer legal and regulatory restrictions on the use of currency elsewhere. Also, the increase in $100s, the denomination with the most significant increase, has been concentrated in one Federal Reserve Cash Office, that serving only New York City and its environs. Tax evasion and other illegal activity cannot explain this geographic concentration. Moreover, if the New York City region actually had a highly unusual distribution of cash, it would surely be reflected in other statistics such as a skewed geographic distribution of vault cash, which is not the case, at least for the District in which New York City is located (table 2). Nor, finally, can tax evasion and other illegal activity explain the data's temporal pattern—for example, the sharp rise in the ratio of currency to M2 that began at the end of the 1980s.

Cross-Country Comparisons

After decades in which many developed countries have supposedly been moving to cashless economies, the sheer size of current per capita currency holdings around the world may come as a surprise (table 7). For two countries, the United States and Germany, part of the mystery is removed when we take the foreign holdings into account.[34] Making such adjustments, the United States per capita holdings move to the low end of the international scale, roughly equal to the per capita levels in Great Britain, Finland, and Canada—countries without significant external holdings of their currencies. Appendix B explores how the relatively high amount in other countries (even in Germany after deducting its foreign holdings) might be explained in the context of an analysis of the demand for money in these developed countries.[35] We conclude that these differences can be explained in part by differences in the principal determinants of currency holdings—interest rates, inflation, and spending. But more important, we believe the differences can be more fully explained by differences in payment systems and practices as well as in the levels of crime and taxation, the availability of ATM machines, the relative size of the denominations in which currency is issued, and, we suspect, the relative strictness of the regulations regarding currency usage.

Summary and Conclusions

One of the purposes of the Federal Reserve System is to provide currency on demand—"to furnish an elastic currency," according to the preamble of the 1913 act creating the Federal Reserve. The original impetus for providing a more flexible currency supply was domestic in nature—for example, at the time, one-third of the population was still engaged in agricultural pursuits and thus subject to the large seasonal swings in agricultural transactions, a great many of

34. Work at the German central bank suggests that between 30 percent and 40 percent of deutsche marks are held outside Germany. See Seitz, "The Circulation of Deutsche Mark Abroad."

35. The balances for Switzerland conceivably include substantial amounts of cash held by nonresidents in safety deposit boxes at Swiss banks. If so, the Swiss data, like that for the United States and Germany, should be adjusted for "foreign" holdings. Currently, almost 90 percent of Swiss currency value is held in three large-denomination notes—100 francs, 500 francs, and 1,000 francs—with almost 50 percent of total currency held in the largest of these. Because 1,000-franc notes rarely circulate in Switzerland, we suspect that some of the currency is held in safety deposit boxes.

7. Comparison of per capita amounts of currency in circulation in selected industrial countries, 1995

Country	U.S. dollars
Japan	3,590
Switzerland	3,450
Germany	2,030
Netherlands	1,550
United States	1,450
Norway	1,410
Belgium	1,350
Germany with foreign holdings removed, assuming 35 percent abroad	1,320
Sweden	1,160
Italy	1,080
Denmark	1,050
France	900
Canada	670
United States with foreign holdings removed, assuming 55 percent abroad	650
Finland	560
Great Britain	530

NOTE. Per capita amounts converted to dollars and rounded to the nearest $10. Some values for 1995 population are extrapolations.

SOURCE. *International Financial Statistics* (International Monetary Fund), Bank for International Settlements, and authors' calculations.

which were undertaken with cash. But within a decade of the act's passage, the Federal Reserve began to collect data on overseas shipments of currency by a number of large commercial banks in New York City, and over the subsequent seventy years, U.S. currency has become the world's leading cash medium. In addition to the dollar's virtues as cash (anonymity and compactness), dollars are held and used because of their liquidity and stability relative to most of the world's currencies. While much of U.S. currency abroad is held in $100s, a significant amount also appears to be in smaller denominations.

Determining how much of U.S. currency has gone abroad or returned from abroad in any period is difficult. Identifying flows between the United States and any individual country is even more problematic. If the flows in both directions stay within the banking system, the banking data we have will often capture much of it. However, if the flows are extraordinarily large, as they appear to have been recently, the outlier methods—the money demand and signal extraction methods—may be able to pick up aggregate net outflows as well.[36]

The difficulty is that not all currency moves across borders within the banking system. Thus, part of our motivation for developing the indirect methods, such as the seasonal and the biometric, was to capture flows that might not show up in the more direct measures. In fact, all of the methods except for that using the CMIR data from Customs suggest that a large amount of currency has gone abroad, and we are inclined to view those expansive estimates as being close to the truth. Does this mean that the methods are inherently good? Or is this just a coincidence? We think it safe to say that the movements abroad have been so large in the 1990s that any reasonable method would have a fair chance of picking them up.

Our ''median flow'' estimates of the amount of currency held abroad and the size of recent overseas flows suggest that more than half of the nearly $300 billion increase in the currency component of M1 since 1976 has gone abroad to accommodate increased demands for Federal Reserve currency (table 6). Higher flows abroad would be registered if we used the shipments proxy (60 percent) and much lower flows would be estimated if we used the Customs data on CMIRs (less than 2 percent). We have also estimated that between 55 percent and 70 percent of the U.S. currency stock is currently held outside the country.

The large expansion of the stock of U.S. currency in the past decade—attributable, as we have seen, to foreign demand—has provided a significant rise in seigniorage to the U.S. Treasury and in the benefit that seigniorage provides to U.S. taxpayers. In the last several years, the Federal Reserve's holdings of U.S. securities (the bulk of the Federal Reserve's balance-sheet counterpart to the stock of U.S. currency outstanding) have yielded annual net earnings—seigniorage—of roughly $15 billion to $25 billion, which is turned over to the U.S. Treasury. Our estimate is that roughly one-half to two-thirds of the earnings is likely attributable to foreign holdings of U.S. currency.

In sum, we now have several methods of determining the stocks and flows of dollars abroad. The estimates are far from identical, but they generally point in the same direction, toward large and increasing quantities of U.S. dollars abroad.

Appendix A: Other Properties of the Median Flow Estimate

Here are details on our investigation of the relationship of the changes in the overall demand for currency and its domestic and foreign components and on considerations in determining a confidence interval for the median flow estimate.

The Median Flow Estimate and Domestic Demand

Recent changes in currency holdings seem to be dominated by the foreign component: While the foreign component has been trending up, the domestic component has been rather flat at an average level of a little less than $7 billion (table 6). To see whether the domestic component responds to economic incentives, we regressed the change in the currency component of M1 on the median flow estimate as well as on variables possibly determining changes in the domestic demand for money.

If the coefficient on the median flow estimate is close to 1 (as it is in the regression reported in table A.1), then we can interpret the remaining coefficients as a domestic money demand function for the annual change in domestic currency holdings. That is, with the full effect of the median flow estimate being captured by the change in the currency component of M1, the result is essentially the same

36. The same also applies to the Cash Office flows, which can be thought of as a crude form of money demand applied to the District or Branch level.

as if we had subtracted the median flow estimate from the change in the currency component and then estimated a money demand function for domestic currency holdings. Of course, if the coefficient on the overseas flow is significantly different from 1, such an interpretation will not hold.

The domestic part of the specification explains the changes in domestic currency holdings by an intercept, the change in the nominal interest rate, and a consumption measure. The change in the nominal interest rate is measured (in the spirit suggested by Lawrence Ball) as the weighted average rate on a narrow alternative to holding currency, namely the components of M2 without any maturity: other checkable deposits, money market deposit accounts, savings accounts, and money market mutual fund accounts.[37] The scale measure is the change in nominal consumption expenditures (excluding those on automobiles, which are generally not bought with currency). The specification is in changes and not in levels because levels (together with lagged stocks to cover distributed lag effects) require accounting for the measurement error in the level of currency abroad.[38]

Each of the estimates has the correct sign, but most of the variance of the change in the currency component, at least at an annual frequency, apparently results from changes in foreign holdings and not domestic holdings. The framework of table A.1 allows us to distinguish the relative contributions in an analysis of variance, and we find that almost 90 percent of the variance of currency changes results from changes in foreign currency holdings (row 2).

37. Lawrence Ball, "Velocity and the Return on Near Moneys," (Johns Hopkins University, June 1995).

38. If we drop any one of the methods from the median calculation, the resulting regression estimates are relatively similar to those shown in table A.1.

Confidence Intervals for the Median Flow Estimate

An advantage of using the median flow estimate as the summary measure of currency flows abroad is that it readily permits statements of confidence intervals. From a statistical point of view, one may regard the seven estimates (one from each of our seven different methods) used in constructing the median flow estimate as a random sample from a continuous distribution of possible estimates; in that case, the sample median that we use is an estimate of the median of the population distribution.

In the example at hand, the median is the middle result obtained from the seven estimation methods and hence can be thought of as a result of discarding the three highest and three lowest estimates of net flows abroad; in that light, variations in confidence intervals for median flow estimates can be constructed on the basis of variations in the number of extreme observations that are excluded from the calculation (chart A.1).[39] For the widest confidence interval, none of the observations are excluded, so that the lower and upper confidence limits are formed by the lowest and highest of all seven observations; for the intermediate interval, the lowest and highest observations are excluded; and for the narrowest, the two lowest and two highest are discarded. These ranges may be useful if one wants to represent some

39. To obtain the widest interval, we drop none of the observations in constructing the range. In that case the probability that the range consisting of the smallest to largest flow would cover the true median in some period is about 0.98; alternatively, if one removed the top and bottom estimates from the set of seven, the resulting confidence interval for the median would be about 0.87; finally if one removed the top two and bottom two estimates, the probability that the resulting interval would cover the true median would be about 0.55. See Robert V. Hogg and Allen T. Craig, *Introduction to Mathematical Statistics,* 5th ed. (Prentice Hall, 1995), pp. 497–98.

A.1. Results of regression of change in currency component of M1 on foreign demand and the determinants of domestic demand, and associated decomposition of variance

Item	Foreign demand, median flow estimate	Determinants of domestic demand			Residual standard error	Covariance term	R^2
		Intercept	Change in nominal interest rates	Change in consumption expenditures			
Regression[1]	.993 (15.1)	5.912 (3.5)	–1.223 (–2.7)	13.096 (.7)	1.3	. . .	.9754
Variance decomposition[2]	52.6 (90.3)		.9 (1.5)		1.7 (2.9)	3.1 (5.3)	. . .

1. Numbers in parentheses are *t* statistics.
2. Numbers in parentheses are the percentages of the variance of changes in currency that are explained by each column or set of columns.
. . . Not applicable.

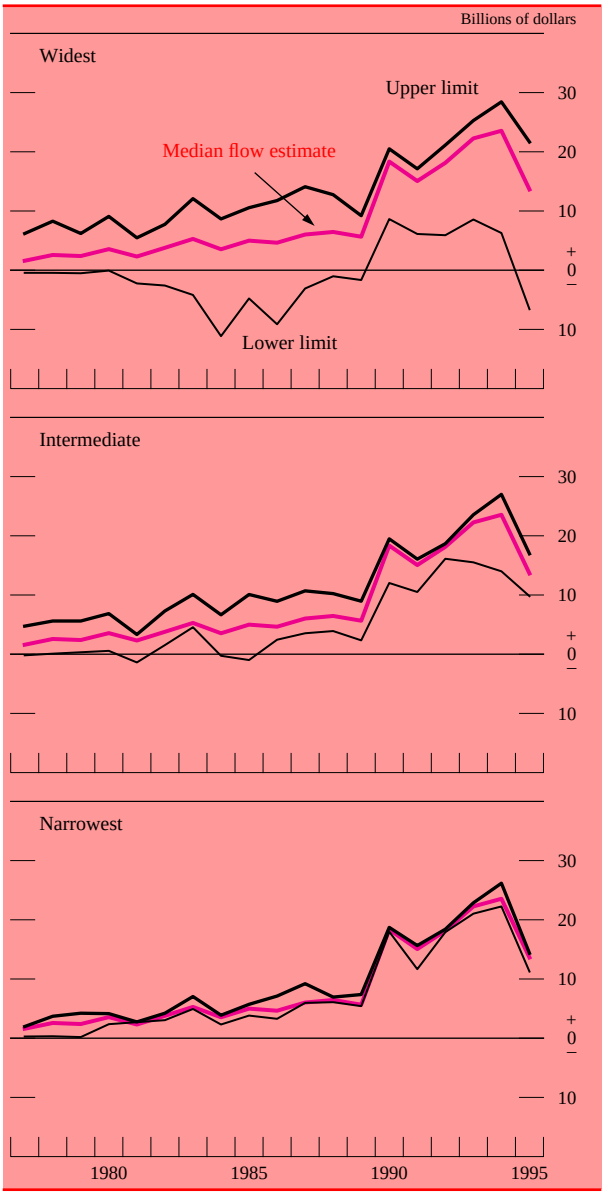
of the uncertainty that exists about net flows of currency abroad.

For that purpose we are inclined to use either the intermediate or narrowest interval: The width of neither interval shows any tendency to trend up over time; the widths are not constant but can get relatively narrow, as in 1990 or 1992, years for which the various methods are in broad agreement about net flows of currency abroad.

Another part of our reason for preferring the two narrowest ranges is that they exclude the smallest observation in each year and thus give less weight to the CMIR data, which generally appear to underestimate net currency flows abroad and produce the smallest flow measure in nearly three-fourths of the periods. This result raises the question of how much the median flow estimate would rise if we excluded the CMIR statistics at the outset: In that case, the resulting summary measure matches the median flow estimate for much of the period and lies slightly above it otherwise; the average amount by which it exceeds the median flow estimate is only $0.5 billion per year.[40]

Alternatively, because the CMIR flows are most often at the bottom of the range of estimates, one could diminish their influence by constructing a confidence interval ranging from the next to the smallest flow to the largest flow in any period; such a range would cover the true median about 93 percent of the time. Further, as an indication of the level of uncertainty about net flows abroad, the implied standard error associated with such a range would currently lie between about $2½ billion and $2¾ billion per year.

A.1. Alternative confidence intervals for the median flow estimate



Appendix B: Estimates of Cross-Country Currency Demand

We investigated the degree to which the cross-country differences in per capita holdings of currency can be explained by various economic factors. We estimated currency demand equations for fourteen developed countries with data covering a seven-year period ending in 1993.[41] The equations have the following specifications:

- The dependent variable, VELOCITY, which is the currency velocity of GNP, that is, the ratio of GNP to the estimated currency holdings that are inside the country but outside the banking system.

40. Taking the median of the six methods excluding the CMIR method would increase the midpoint estimate of the amount held abroad slightly, from 55 percent to 57 percent.

41. In our specification, all the variables are natural logs of the underlying series, and the variable names are written in small capital letters. We thank David B. Humphrey and his collaborators for making their cross-country currency data available to us (see David B. Humphrey, Lawrence B. Pulley, and Jukka M. Vesala, "Cash, Paper, and Electronic Payments," *Journal of Money, Credit, and Banking*, vol. 28, November 1996, part 2, in press). The only variable that we have added is RATIO OF REVENUE TO GDP from Robert Summers and Alan Heston, "The Penn World Table (Mark 5): An Expanded Set of International Comparisons, 1950–1988," *The Quarterly Journal of Economics*, vol. 106 (May 1991), pp. 327–68. We used an updated version, Mark 5.5, available by anonymous ftp from ftp://nber.harvard.edu.

• Two opportunity cost terms, an interest rate (NOMINAL RATE) and the rate of inflation (INFLATION RATE). Higher opportunity costs tend to induce currency holders to reduce their holdings, resulting in higher currency velocities.

• Two "scale" terms. The first, RATIO OF REVENUE TO GDP, accounts for the velocity effect of the underground economy: If government raises taxes, tax avoidance will rise, leading to more production in the off-the-books (cash) sector, which in turn increases the amount of currency per unit of output and thus works to lower velocity.

The second scale term is VIOLENT CRIME per 100,000 population. The effects of crime are ambiguous: On one hand, street crime is likely to reduce currency holdings (raise velocity) because of fear of being robbed; on the other hand, various forms of criminal activities involve the use of currency.

• The total estimated number of noncash payments, NONCASH PAYMENTS, per capita. Presumably, other things equal, an economy with a higher level of noncash payments will have lower currency holdings and higher currency velocities.

• The number of automated teller machines, ATM, per capita. The effect of ATMs is ambiguous. On one hand, more ATMs reduce the cost of obtaining currency and thus should lower currency obtained per transaction and overall currency holdings. On the other hand, lowering the cost of obtaining currency could also make it more convenient relative to other transaction media such as credit cards, thus increasing overall currency holdings and lowering velocity.

The last factor we consider accounts for the notable differences that exist among countries in the purchasing power associated with the largest denomination of domestic currency that is generally available. For example, the largest denomination in active circulation in Japan (the ¥10,000 note), the United Kingdom (the £50 note), and the United States (the $100 note) range in value in dollar terms from about $78 to $100 as of this writing; these values represent considerably less purchasing power than that of the largest denominations in Canada, Germany, the Netherlands, and Switzerland, all of which have 1,000-unit bank notes, which now range in value from about $600 to $830. Categorizing some countries as "low-denomination" (those in which the largest denomination has relatively low purchasing power) and others as "high-denomination," we find that significant differences emerge between the two groups in the responsiveness of their currency demand functions. For example, for both groups, increases in the price level tend to redirect more transactions toward the largest denomination; but, for low-denomination countries, another effect of inflation may be more important: the substitution out of currency into other means of payment for large-value transactions that would otherwise require an inconvenient amount of cash to execute.

The specification we estimate uses a pooled panel regression with different slopes for the low-denomination and high-denomination countries (table B.1). The opportunity-cost elasticities in the low-denomination countries are higher (in absolute value) than those in the high-denomination countries, perhaps because of the above-mentioned substitution effect in low-denomination countries as rising prices

B.1. Pooled panel-data regressions for currency velocities

Variable	Low-denomination countries	High-denomination countries
NOMINAL RATE	4.47 (3.0)	1.21 (.4)
INFLATION RATE	7.52 (3.9)	5.05 (1.4)
RATIO OF REVENUE TO GDP	–.70 (–4.7)	–.81 (–5.9)
VIOLENT CRIME	–.02 (–.3)	.29 (1.5)
NONCASH PAYMENTS	.70 (7.2)	1.60 (5.6)
ATM	–.15 (–1.8)	–.36 (–3.3)
INTERCEPT	1.82 (4.3)	–3.40 (–4.1)
R^2	.78	.79
Number of observations	60	34

NOTE. Numbers in parentheses are *t* statistics.

B.2. Actual real per capita holdings of currency in selected industrial nations compared with holdings predicted by pooled panel-data regressions for velocity

U.S. dollars

Country	Actual	Predicted
Low-denomination countries		
Denmark	714	839
Finland	407	610
France	784	650
Italy	943	1,028
Japan	2,247	2,033
Norway	1,132	924
Sweden	1,108	840
United Kingdom	462	520
United States[1]	358	340
High-denomination countries		
Belgium	1,178	1,281
Canada	618	648
Germany[2]	906	1,067
Netherlands	1,309	1,057
Switzerland	2,732	2,566

NOTE. Holdings are averages for 1987–93. Dollar values deflated by the chain-type price index for personal consumption expenditures, 1992 base year.

1. After removal of foreign holdings, which were estimated using midpoint of overseas stock from the median flow estimate.

2. After removal of estimated foreign holdings (35 percent of total).

intensify the inconvenience of their low purchasing power currency.[42] Except for the effect of crime, which is ambiguous, all of the variables appear to have the expected signs and are generally quite significant.[43]

The underground economy effects (RATIO OF REVENUE TO GDP), are similar in magnitude in both types of countries and appear to have powerful explanatory effects. The ATM results are especially significant in the high-denomination countries and indicate that the convenience effects dominate the transaction-cost effects. The difference between the intercepts in the two specifications implies that residents in the high-denomination countries hold on average about $185 more in currency than their counterparts in low-denomination countries. Excluding foreign holdings from the domestic currency stock of Germany and the United States yields values that on average tend to track the currency series in the various countries, with about 80 percent of the variation in velocity explained by the specification in both types of countries (table B.2).

In sum, the cross-country differences in currency holdings appear to be somewhat explicable by the basic factors we have been considering, including the magnitude of the largest denomination in which currency is issued. To be sure, consideration of such denomination effects, as well as of the NONCASH PAYMENTS variable, may also embody other aspects of the demand for currency, such as the regulatory environment in which bank notes are handled. □

42. Using a Chow test, we solidly reject the hypothesis that the corresponding slope coefficients in the velocity specifications are equal in the high- and low-denomination countries; the test statistic equaled 5.50, which has a p value of 0.0001.

Both opportunity cost variables (NOMINAL RATE and INFLATION RATE) are measured as a gross return so that we treat them symmetrically and can take logs for the deflation of the price level that occurs in the sample. As a result, the coefficient of the elasticity of real money balances with respect to these opportunity costs measured as a net return (the more usual way of introducing such variables) will be $x / (1 + x)$ times the gross elasticity, where x is a fraction; for example, a 5 percent rate would imply that the elasticity on the gross return should be reduced by $0.05 / 1.05 = 0.0471$ to express it as an elasticity on a net return.

43. The crime variable has different signs in the two regressions and is insignificant in either case. The underground economy effects (RATIO OF REVENUE TO GDP) are similar in magnitude. We believe on balance that crime should reduce currency holdings and thus increase velocity. We find such a result for the high-denomination countries, and it is marginally significant on a one-sided test of statistical significance.

The opportunity-cost elasticities in the high-denomination countries are not significant, perhaps because of the relatively low number of degrees of freedom.