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This paper provides a consistent, monthly measure of the amount of the U.S. adjusted monetary base that is domestically held, and of the amount held abroad. Most macroeconomic models that address the role of outside money as a determinant of the economy's aggregate price level are closed economy models, suggesting a need to accurately measure the domestic monetary base. To do so, this paper presents a new method to estimate the amount of U.S. currency held abroad, a method which exploits data on the processing of currency at the Federal Reserve's 37 cash offices. Estimates of domestic monetary aggregates, including domestic M1 and M2, also are produced. Relative to previous studies and estimates currently included in the Flow of Funds and the National Income and Product Accounts, our estimates suggest larger currency exports during the 1970s and early 1980s, and a sharp slowing of exports since 1995.

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The Domestic Adjusted Monetary Base

Economic theory predicts that the price level in a fiat-money economy is anchored by "outside money," or the liabilities of the monetary authorities. Early theoretical analyses of this relationship include Gurley and Shaw (1960), Patinkin (1963) and, somewhat later, Brunner and Meltzer (1976) and Fama (1983); more recent general equilibrium models include King and Plosser (1984), Chari, Christiano and Eichenbaum (1995), and Coleman, Gilles and Labadie (1996); notable empirical examples include the series of papers by Bennett McCallum and co-authors (McCallum and Hargraves, 1996; McCallum, 1988, 1990, 1993, 1995, 1997). Because these and most similar models omit a foreign sector, they are in all essential aspects models of the determination of the aggregate price level in a closed economy. Hence, application of the models to real-world open economies requires one to measure separately the domestic and foreign-held components of a country's stock of outside money, that is, of its monetary base.

Such a partition is particularly important for two of the world's largest economies—Germany and the United States.[1] Outside money for the United States economy is measured as its *monetary base*, which consists primarily of the liabilities of the Federal Reserve to households and firms. Currency in the hands of the public is the largest part of the monetary base, and exports of currency from the United States likely account for as much as half of the increase in the monetary base during the last decade. Reflecting its importance, quarterly estimates of foreign-held US currency are now included in the Federal Reserve System's *Flow of Funds Accounts of the United States* and in the Bureau of Economic Analysis's estimates of the net international investment position of the United States.[2] In the July 1997 revision of the National Income and Product Accounts, the introduction of estimates of foreign-held US currency reduced the estimated net foreign asset position of the United States by more than $300 billion.

This paper presents measures of the domestic and foreign-held components of the U.S. adjusted monetary base.[3] The principal problem in building such measures is separating domestic and foreign holdings of U.S. currency. No direct observations are available regarding the

[1] On Germany, see Deutsche Bundesbank (1995). Anecdotal reports also suggest that large numbers of Swiss 1000 fr notes are held outside Switzerland but measures of the amount are very tentative; see Andrist (1997).
[2] On the former, see Board of Governors (1996); on the latter, see Bach (1997) and Scholl (1997).
[3] That is, the monetary base adjusted for the effects of changes in Federal Reserve statutory reserve requirements on the quantity of base money demanded by banks.

amount of U.S. currency held abroad, nor of the total amounts shipped to and received from other countries.[4]

Anecdotal reports suggest that large numbers of US Federal Reserve notes in most denominations are in continual foreign circulation, and that at least some portion of each denomination flows into and out of the United States with business travelers and tourists on a more or less regular basis. Yet, these and other reports also suggest that the overwhelming majority of the *dollar value* of foreign-held US currency is comprised of $50 and $100 notes that tend to remain abroad once there, and are held not only as a medium of exchange but also as a hedge against uncertain inflation and political instability.[5]

In an important study, Porter and Judson (1996) examine eleven different methods to estimate the annual net flows of US currency into foreign circulation during 1977–95.[6] Combining these flow estimates with a benchmark assumption that about 50 percent of the stock of US currency outside banks was held abroad at the end of 1976, they conclude that, by the end of 1995, the proportion of US currency held abroad had increased to about 55 percent; 44 percent of the 55 percent is in the form of $100 Federal Reserve notes.[7] Their published estimates have several shortcomings that make them unsuitable for constructing a domestic monetary base, or any other domestic monetary aggregate: no estimates are available before 1977; the estimates are only for annual net outflows; the benchmark assumption that half of US currency was held abroad in 1976 is implausible; and, their preferred median-flow estimator is impossible to update in a timely fashion.

The net outflow of U.S. currency to foreign circulation has also been considered by Feige (1994, 1996). His preferred method, the "shipments proxy," is based on three assumptions: all (or at least, most) foreign-held US currency is $100 notes; all (most) exports and im-

[4] Porter and Judson (1996)'s "foreign currency shipments" method utilizes specific, firm-level data on the amounts of currency shipped abroad. The firms that furnish the data to the Federal Board staff regard the data as proprietary, and hence the data are not available to the public nor to other researchers.
[5] Bach (1997), p. 49, notes that "…mostly lower denomination notes ($5s, $10s, $20s and $50s) circulate in the U.S. economy, whereas mostly $100 notes circulate abroad." See also Porter and Judson (1996).
[6] The methods are summarized in Porter and Judson (1996), Table 4. The eleventh method, "median flow," is not an independent method, but rather a summary method, defined over the other ten. In correspondence, Porter notes that the correlations among the estimates obtained by the median-flow, cash-office, and shipments-proxy methods exceed 0.95, and that the median-flow estimate is the cash-office or shipments-proxy estimate in about three-quarters of their observations. Yet, in their article, they clearly focus on the median-flow method: the only annual flow data in the article are the median flow estimates. Subsequent publications, such as the Flow of Funds and the National Income and Product Accounts, contain estimates based on the shipments-proxy method, which may be updated promptly each month.
[7] Porter and Judson (1996), p. 895-6, Table 5.

ports of $100 notes occur at one, or perhaps two, Federal Reserve System cash offices; and none (or almost none) of the net outflow of $100 notes at those offices reflects changes in the domestic demand for $100 notes.[8] The estimated amounts of foreign-held US currency shown in the Flow of Funds and the National Income and Product Accounts are obtained by applying this method to the New York City and Los Angeles cash offices' net outflows of $100 notes (Bach, 1997).[9] These estimates, as well as Porter and Judson's, are discussed more fully below.

The balance of the paper is organized as follows. In the following section, we present a model to partition net shipments of currency into the proportions entering domestic and foreign circulation, respectively. In the second section, we use the model to construct estimates of domestic and foreign currency holdings. In the third section, we compare these estimates to those in previous studies and those included in the Flow of Funds and National Income and Product accounts. In the fourth section, we compare the implied domestic adjusted monetary base to the total adjusted monetary base, and examine implications for monetary policy. Finally, we use our estimates of foreign-held currency to construct "domestic" measures of the monetary aggregates M1 and M2.

1. A Model to Estimate Foreign Holdings of US Currency

Our model to estimate the amount of foreign-held U.S. currency utilizes data on the receipts and shipments of currency, by denomination, at the Federal Reserve's 37 cash offices.[10] We separate the net outflows of $50 and $100 Federal Reserve notes from these offices into a portion that remains in domestic circulation and a portion that is exported into "permanent" for-

[8] The shipments proxy is also examined by Porter and Judson (1996).

[9] The method used in the Flow of Funds Account has apparently changed through time. Introductory notes in the December 1996 Flow of Funds release (Z.1) refer the reader to Porter and Judson (1996); inspection confirms that the Flow of Funds data are Porter and Judson's median-flow estimates. Yet, in the September 1997 release (for the second quarter of 1997), the Flow of Funds historical data were changed to match those published in the July 1997 *Survey of Current Business*. The latter, according to Bach (1997), are not the median-flow estimates but rather are a new set of data obtained by application of the shipments proxy method to net outflows of $100 notes at the New York City and Los Angeles cash offices. This change in the method used to estimate foreign-held currency is not mentioned in the Flow of Funds Z.1 release.

[10] The Federal Reserve ships and receives currency at 37 cash offices nationwide (primarily Federal Reserve Banks and their branches). Data for these offices are available on Federal Reserve electronic data bases beginning January, 1974. Historical data back to January, 1958 are available on archival microfilm. Our estimates utilize both these sources of data.

eign circulation.[11] This method furnishes monthly estimates of both the flow of U.S. currency to foreign circulation and, conditional on our assumed benchmarks in 1965 and 1969, the total foreign-held stock of U.S. currency. Because all required data are available shortly after the end of each month, these estimates may be updated on the same schedule as other currently published monetary aggregates.[12]

In our method, the fundamental data are the number of pieces of currency of each denomination put into circulation (E_t = emissions) and received from circulation (R_t = receipts) each month by Federal Reserve cash offices. These flows into and out of circulation are related to the amount of currency in circulation of a particular denomination, C_t, by the identity:

$$(1) \qquad \Delta C_t \equiv E_t - R_t.$$

Currency of a particular denomination put into circulation (E_t) either circulates domestically (E_t^D) or is exported and circulates abroad (E_t^F).

Because no direct estimates of either exports of U.S. currency nor the foreign-held stock exist, some set of identifying assumptions is necessary. The assumptions we choose are:

- First, that currency once exported tends to stay abroad and hence has been permanently removed from domestic circulation. This allows us to assume that currency received from circulation by Federal Reserve cash offices reflects (almost) exclusively domestic circulation, that is $R_t = R_t^D$.

- Second, that small denomination notes – $1s, $5s, and $10s – carried abroad tend to circulate into and out of the U.S., and hence into and out of Federal Reserve cash offices, in a manner similar to the internal domestic circulation of the same denomination notes.

- Third, that the emissions and receipts patterns of small denomination notes at Federal Reserve cash offices are good measures of the unobservable emissions and receipts patterns of the large denomination notes in domestic circulation. In particular, for reasons examined

[11] Our method seeks to estimate the share of U.S. currency that tends to remain abroad in continual circulation, either as a medium of exchange or as a store of value. Our method is robust to routine inflows and outflows of small-denomination currency; see the discussion of our Assumptions 1 and 2.

[12] Data on monetary aggregates during a given month are first published by the Board of Governors on the second Thursday after the Monday date of the week, ending on a Monday, that contains the final calendar day of the previous month. On average, new monthly data appear about 2 weeks after the end of the respective month.

below, we rely on the pattern of emissions and receipts of $10 notes at the New York City cash office to construct our estimates of the foreign circulation of large denomination notes.

Assumption 1: Currency Abroad Tends to Stay Abroad

Anecdotal evidence suggests that much U.S. currency held abroad is infrequently repatriated to the United States. Although some currency enters and leaves the U.S. each day with businessmen and tourists, and some currency certainly is returned to the United States when foreign stocks exceed desired levels, U.S. currency abroad acts as both a store of wealth and medium of exchange. Surges in currency exports have tended to be correlated with increases in economic and/or political instability and, because of its dual role as a medium of exchange and store of value, currency may be retained abroad as a hedge against future instability even after the immediate crisis subsides. Phrased somewhat differently, once households and firms are induced by political and economic instability or by transactions needs to allocate some part of their portfolio to U.S. currency, that share perhaps tends to change slowly.

In our analysis, we seek to identify the proportion of US currency that is in continual circulation, or permanently held, abroad. We assume, as an identifying assumption, that there is a permanent and transitory component to foreign-held US currency. As a matter of definition, the permanent component reflects currency which is in continual circulation abroad and hence does not flow through Federal Reserve cash offices.[13] We assume that currency held temporarily abroad, say due to tourism or business travel, returns to the United States (and hence to Federal Reserve cash offices) with the same transit time as currency in domestic circulation; an alternative, equivalent assumption is that the ratio of currency temporarily held abroad to currency in domestic circulation is constant. Conditional on these assumptions, receipts of currency at Federal Reserve cash offices reflect the amount of currency in domestic circulation (outside banks) plus any currency temporarily held abroad, and the methodology developed herein provides a measure of the amount of U.S. currency that is in continual circulation outside of the United States.

Assumption 2: Domestic and Foreign Circulation Patterns for Small Denomination Notes

Our second assumption implies that, through time, emissions of small denomination notes from Federal Reserve cash offices should be approximately equal to receipts (net of the growth of the economy), and that the seasonal variation in the quantity of these notes in circula-

tion should vary relatively little through time; that is, that the pattern of Federal Reserve cash office currency processing activity for small denomination notes should be uncorrelated with both the level and growth rate of foreign-held U.S. currency.

The ratio of emissions to receipts, $\left(\frac{E_t}{R_t}\right)$, for $1, $5, $10 and $20 notes at Federal Reserve cash offices nationwide and at the New York City cash office are shown in Figure 1. For aggregate nationwide data, the ratios for the first three denominations display the stable patterns suggested by assumption 2. The ratio for $20 notes displays a relatively less constant mean and seasonal pattern, both nationwide and at New York City. On balance, we conclude that $10 notes are the largest denomination with a relatively stable mean and seasonal pattern, both nationwide and at the New York City cash office, and hence are most suitable for our analysis.

Figure 2 focuses on the ratios of emissions to receipts for $10 notes, at all Federal Reserve cash offices outside New York City, $\left(\frac{E_t}{R_t}\right)^{non-NYC}$, in the top panel, and at New York City, $\left(\frac{E_t}{R_t}\right)^{NYC}$, in the center panel, for January 1965–August, 1999. (The data are monthly, not seasonally adjusted.) The bottom panel of the Figure shows the ratio of emissions to returns at the New York City office divided by the ratio at all other cash offices,

$$\left(\left(\frac{E_t}{R_t}\right)^{NYC} \Big/ \left(\frac{E_t}{R_t}\right)^{non-NYC}\right).$$

Although there is some irregularity in the New York City data during the late 1980s, this compound ratio displays several distinct characteristics: (1) a strong but remarkably constant seasonal pattern; (2) no distinct trend; and, (3) a mean for the numerator, the New York City cash office ratio, equal to 1.11, about ten percent higher than the mean of the denominator, the aggregate of the other 36 Federal Reserve cash offices, equal to 0.998. Note that because the mean of the denominator is not significantly different from 1.0, *all* growth in the outstanding stock of $10 Federal Reserve notes in circulation has come (algebraically) from the New York City office.

[13] We of course do not mean that precisely the same paper notes stay abroad (although many perhaps do), but rather that the aggregate value held abroad tends to be stable.

Assumption 3: The Domestic Circulation of Large Denomination Notes

Our third identifying assumption is that the emissions-to-receipts patterns at Federal Reserve cash offices of large denomination ($50 and $100) notes in domestic circulation can be measured by the emissions-to-receipts pattern of smaller denomination notes. We believe that it is reasonable to assume that large denomination notes in domestic circulation will pass through Federal Reserve cash offices in the same fashion as smaller denomination notes ($1, $5, $10). Since there are no data on the separate domestic circulation patterns of large and small denomination notes, this assumption is not testable—but it is supported by the data analyzed below.[14]

Our subsequent analysis is based on the New York City cash office ratio, $\left(\frac{E_t}{R_t}\right)^{NYC}$, for $10 notes. We choose the New York City ratio, rather than the non-New York ratio, so as to generate a conservative estimate of the amount of currency going to foreign circulation, that is, we prefer to under, rather than over, estimate the amount being shipped abroad. (The reason for this bias will become clear below, when we compare our estimates to others.) The New York City cash office ratio provides such a conservative estimate because it allows for more growth in the *domestic* circulation of large denomination notes than would be obtained if we used the nationwide ratio for all cash offices: recall that the aggregate data for all cash offices outside New York City shows no secular growth in the outstanding stock of $10 Federal Reserve notes since 1965.

Specifically, for large-denomination Federal Reserve notes in domestic circulation, let the ratio of emissions to receipts be denoted as:

$$(2) \qquad \mu_{Lt} = \frac{E_t^{DL}}{R_t^{DL}}$$

[14] Some readers have objected to this assumption on the grounds that the domestic velocity of circulation of large denomination notes may be much smaller than for small denomination notes. This is a misinterpretation. Our method relies on the ratio of emissions to receipts of notes at Federal Reserve cash offices, and not at all on the ratios of emissions and/or receipts of notes to the outstanding numbers of notes or to measures of aggregate economic activity. The appropriateness of our method is independent of differences by denomination in the velocity of circulation of domestically held currency. One other reader has objected by asserting that banks tend to return small denomination notes to the Federal Reserve for processing more frequently that large denomination notes, perhaps because newly issued small denomination notes deteriorate in circulation more rapidly than large denomination notes. This objection also is a misinterpretation. Even if the proportion of notes that banks return to the Federal Reserve differs by denomination (and it likely does), our results—which depend on the ratios of Federal Reserve cash office shipments to receipts by denomination—would be affected only if the tendency for banks to return notes to the Federal Reserve has changed differentially by denomination through time. We doubt that this has occurred.

where E_t^{DL} are emissions to domestic circulation, R_t^{DL} are receipts from domestic circulation, and the superscripts and subscripts are: "D" denotes domestic flows, "F" foreign flows, "L" large denomination notes, and "S" denotes small denomination notes. Our estimator $\hat{\mu}_{Lt}$ is the ratio of emissions (E_t^S) to receipts (R_t^S) of \$10 denomination notes at the New York City cash office:

$$\hat{\mu}_{Lt} = \mu_{St} = \frac{E_t^S}{R_t^S}, \tag{3}$$

Recall from assumption 2 that $R_t^L = R_t^D$, that is, receipts of large denomination notes from (permanent) foreign circulation are zero by assumption. An estimate of emissions of large denomination notes to domestic circulation is:

$$\hat{E}_t^{DL} = \hat{\mu}_{Lt} R_t^L \tag{4}$$

or:

$$\frac{\hat{E}_t^{DL}}{E_t^L} = \hat{\mu}_{Lt}\left(\frac{R_t^L}{E_t^L}\right). \tag{5}$$

Since $E_t^L = \hat{E}_t^{DL} + \hat{E}_t^{FL}$,

$$E_t^L = \hat{\mu}_{Lt} R_t^L + \hat{E}_t^{FL} \tag{6}$$

and estimated emissions to permanent foreign circulation are:

$$\hat{E}_t^{FL} = E_t^L - \hat{\mu}_{Lt} R_t^L \tag{7}$$

or:

$$\frac{\hat{E}_t^{FL}}{E_t^L} = 1 - \hat{\mu}_{Lt}\left(\frac{R_t^L}{E_t^L}\right). \tag{8}$$

Both E_t^{DL} and E_t^{FL} are emissions, and hence necessarily are > 0. Since R_t^L is receipts, it is also necessarily > 0. The factor μ_{St} is > 0, since the ratio $\frac{E_t^S}{R_t^S}$ is a positive number.

By (5) it is guaranteed that the estimated gross emissions (shipments) of large denomination notes to domestic circulation is positive, $\hat{E}_t^{DL} > 0$. This is, of course, reasonable: *true* gross shipments, E_t^{DL}, cannot be negative. However, since the estimated foreign shipments, $\hat{E}_t^{FL}$, is computed as the difference between two positive numbers, there is no guarantee that it

will be nonnegative. We regard negative values of $\hat{E}_t^{FL}$ as a reflecting either data errors or specification errors in our model. Estimated foreign gross shipments will be negative, $\hat{E}_t^{FL} < 0$, when the ratio $\frac{\hat{E}_t^{DL}}{E_t^{L}} > 1.0$, that is, when estimated emissions to domestic circulation exceed total emissions of large denomination notes. Because $E_t^{FL} < 0$ is not feasible (actual gross shipments of currency are always nonnegative), we regard values of $\hat{E}_t^{FL} < 0$ as inadmissible and impose the restriction in our method that $\frac{\hat{E}_t^{DL}}{E_t^{L}} \leq 1$ or equivalently $\hat{E}_t^{FL} \geq 0$.

The most likely cause of $\hat{E}_t^{FL} < 0$ is that, contrary to our assumptions, some receipts of large denomination notes at Federal Reserve cash offices came from foreign circulation: Recall that $\hat{E}_t^{FL} = E_t^{L} - \hat{\mu}_{Lt}\hat{R}_t^{DL}$, that $\hat{R}_t^{DL} = R_t^{L} - \hat{R}_t^{FL}$, and that $\hat{R}_t^{FL} = 0$ for all t by assumption. Even if $\hat{E}_t^{FL} > \hat{R}_t^{FL}$ for all *t*, such that the stock of large denomination U.S. currency held abroad never decreases, some large denomination notes received at the cash offices might have come from abroad, that is, $\hat{R}_t^{FL} > 0$. As with most foreign currency transactions, such foreign receipts, if any, are not observable and hence inevitably remain as estimation error. Finally, note that $\hat{E}_t^{FL} < 0$ should occur less frequently for notes that are more heavily in demand abroad—that is, for notes where the assumption $\hat{R}_t^{FL} = 0$ is true for more values of *t* (or at least $\hat{R}_t^{FL}$ is very small)—and should occur more frequently for notes that are less heavily (or decreasingly) in demand abroad; in what follows, this is exactly the relative pattern we find for $50 and $100 dollar notes, respectively.

2. Estimates of Foreign-Held Large Denomination Federal Reserve Notes

The monthly ratios of emissions to receipts at the New York City cash office and at all other cash offices for $10, $50 and $100 Federal Reserve notes are shown in Figure 3. In this figure, the ratios for $10 and $100 notes begin January 1965, and the ratio for $50 notes in January 1969.

A. $100 Notes

The emissions-to-receipts ratios for $100 notes are much different than those for the $10 notes. At both the New York City cash office and the other cash offices, the emissions-to-receipts ratio is considerably in excess of 1.0 throughout the sample period (averaging 2.3 for the New York office and 1.3 for the others). Such high ratios of emissions to receipts are not characteristic of the smaller ($1, $5, $10) denomination notes. This contrast between the ratios for small and large denomination notes strengthens the case for our assumption 2.

A comparison of the emissions-to-receipts ratios for the New York City and the other cash offices suggests several reasons to question the shipments-proxy assumptions of Feige (1996) and of Porter and Judson (1996) that all emissions of $100 notes to foreign circulation came from the New York City office.[15] Before the 1980s, the emissions-to-receipts ratios at the New York City and non-New York City cash offices have approximately the same mean. This lends support to the view that exports of currency were more closely linked to business travel and tourism than to political and economic instability abroad, and hence also were perhaps more widely distributed among cash offices. Although not strong, there appears to be a slight positive trend in the emission-to-receipts ratio at the New York City cash office, at least prior to the 1990s, and a slight negative trend at all other cash offices, suggesting that exports have tended to become more concentrated at the New York City cash office during our sample period, from 1965–1998. An implication of this trend is that at least some significant portion of exported currency must have come from non-New York City offices prior to 1990.[16] Additional support comes from comparing the ratios of emissions-to-receipts of $100 and $10 notes at New York City,

$$\left(\left(\frac{E_t^{\$100}}{R_t^{\$100}} \right)^{NYC} \Big/ \left(\frac{E_t^{\$10}}{R_t^{\$10}} \right)^{NYC} \right)$$

to the comparable ratio for non-New York City cash offices,

[15] The shipments proxy used to obtain estimates for the Flow of Funds Accounts and the National Income and Product Accounts includes the Los Angeles cash office, as well as the New York City cash office. These data are examined further later in this article.

[16] Note that, to the extent this is true, estimates based primarily on shipments from the New York City cash office will tend to underestimate the amount of currency exported; this perhaps also explains, in part, why Porter and Judson's estimated foreign-held shares of US currency decrease during the 1970s and 1980s. This topic is explored further below.

$$\left(\left(\frac{E_t^{\$100}}{R_t^{\$100}} \right)^{non-NYC} \Big/ \left(\frac{E_t^{\$10}}{R_t^{\$10}} \right)^{non-NYC} \right).$$

If little of the currency shipped from cash offices outside New York City was exported, then one might expect the emissions-to-receipts ratio for the total of these offices to more closely resemble their ratio for small-denomination currency. In fact, the ratio for offices outside of New York City seems too large to support the position that all foreign shipments of $100 notes originated from the New York City cash office.

Focusing on the New York City emissions-to-receipts ratio, inadmissible occurrences of $\frac{\hat{E}_t^{DL}}{E_t^{L}} > 1.0$ (that is, $\hat{E}_t^{FL} < 0$) based on equation (5) appear fairly often for January observations, as shown in Figure 4. Albeit partially seasonal, this volatility also perhaps reflects the ebb and flow of currency exports in response to events abroad: Inadmissible values are more frequent during periods of slower exports, such as the mid-1980s, and less frequent during accelerations of exports, such as in the early 1990s. As discussed above, we cap (that is, allow a maximum value of) $\frac{\hat{E}_t^{DL}}{E_t^{L}}$ at 1.0 and apply equation (7) to the emissions and receipts of $100 notes at the total of all Federal Reserve cash offices during January 1965–August 1999.[17]

Estimated net outflows of $100 notes to foreign circulation are shown in Figure 5, and cumulative stocks of domestically and foreign-held $100 notes are shown in Figure 6; the latter are constructed by assuming that the quantity of foreign-held $100 notes was zero in December 1964. As described above, the net change in the domestic stock of $100 notes equals the estimated domestic emissions, $\hat{E}_t^{DL}$, minus total receipts of $100 notes, R_t. The net change in the foreign-held stock of $100 notes equals the estimated foreign emissions, $\hat{E}_t^{FL}$, because, by assumption, receipts from (permanent) foreign circulation are zero.[18] Our estimates suggest that of the $336 billion (net) of $100 notes that were emitted to circulation from January 1965 through August 1999, only an estimated $116 billion remained in domestic circulation, while an esti-

[17] To examine the robustness of our results to this constraint, we have also examined quarterly and annual ratios of currency emissions to receipts. At the quarterly level of aggregation, very few observations of the emissions-to-receipts ratio exceed one, and those few observations are very close to one. Our estimated flows to foreign circulation are little changed. These results are available from the authors on request.

[18] By definition, any $100 notes returned to U.S. banks, and thereafter to the Federal Reserve, cannot be in continual, permanent circulation abroad.

mated $220 billion were exported abroad. On August 1999, the estimated cumulative exports of $100 notes accounted for about 45 percent of total US currency held outside banks (the currency component of M1). The benchmark from which this estimate is constructed is discussed further below.[19]

B. $50 Federal Reserve Notes

In addition to $100 notes, some reports suggest that significant quantities of $50 notes are in permanent foreign circulation. The ratios of emissions-to-receipts for $50 Federal Reserve notes at the New York City cash office and at all other cash offices are shown in Figure 3 for January 1969–August 1999.[20] The characteristics of these ratios suggest that: past exports of $50 notes are today a significant portion of foreign-held US currency; that most of these exports came from the New York City cash office; and, that relatively few $50 notes have been exported in recent years, relative to exports of $100 notes.

The first notable characteristic of these ratios is their size. At both the New York City and other cash offices, the ratios are considerably in excess of 1.0 throughout the sample period, averaging 2.2 for the New York office and 1.1 for all other offices. Further, the mean of the emissions-to-receipts ratio for the New York City cash office, 2.2, is almost equal to the mean of that office's emissions-to-receipts ratio for $100 notes, 2.3, during January 1965–August 1999. The emissions-to-receipts ratio for the New York City cash office does not exhibit any trend, while the ratio at all other cash offices has a negative trend and is close to 1.0 in recent years, suggesting few exports from cash offices other than New York City.

Inadmissible values of $\frac{\hat{E}_t^{DL}}{E_t^{L}} > 1.0$ (that is, $\hat{E}_t^{FL} < 0$) are observed more frequently for $50 notes than is the case for $100 notes (see Figure 7). Before 1983, these observations occur mostly in January; since then the fraction of such observations during each year has been increasing. This increasing frequency reinforces other evidence which suggests that in recent years relatively few $50 notes have been exported. As above, we impose a maximum value of 1.0 on

[19] The benchmark from which this estimate is constructed assumes that the quantity of foreign-held $100 notes was zero in December 1964. Our estimate is robust to the benchmark assumption. Because the total value of $100 Federal Reserve notes in circulation in December 1964 was only $7.6 billion, even if fifty percent of the stock of such notes at that time was held abroad, which seems unlikely, the additional accumulation of estimated exports of $100 notes would only increase the fraction of total currency held abroad to 47 percent.

$\frac{\hat{E}_t^{DL}}{E_t^L}$ and apply equation (7) to estimate emissions and receipts of $50 notes to permanent foreign circulation.

Estimated net outflows of $50 notes are shown in Figure 8, and the accumulated stocks of domestically and foreign-held $50 notes (conditional on the assumption that no such notes were held abroad in December 1968) are shown in Figure 9. Of the $49.9 billion of $50 notes that were emitted to circulation from January 1969 through August 1999, we estimate that $20.3 billion remain in domestic circulation, while an estimated $29.6 billion are held continually abroad. On August 1999, the fraction of currency held by the nonbank public accounted for by foreign holdings of $50 notes is approximately 6 percent. This estimate is constructed by benchmarking total $50 notes outside the United States at the end of 1968 to zero.[21]

C. Growth Rates of Total, Domestic and Foreign-Held Currency

Monthly growth rates of the estimated domestic and foreign currency components (of total currency in M1), seasonally adjusted, are shown in Figure 10.[22] The estimated foreign component displays significant seasonality, especially before 1980.[23] This seasonality perhaps reflects a largely transaction-based demand for, and use of, U.S. currency abroad during the early part of our sample; that is, the quantity of U.S. currency abroad fluctuated with seasonal fluctuations in business activity as it moved into foreign countries. During the latter parts of our sample, and especially after 1980, the increased demand for U.S. currency abroad as a store of value—caused by political unrest and inflation instability—might tend to mask seasonal flows, particularly when holdings retained abroad are growing rapidly.[24]

The well-known strong monthly seasonality of currency demand suggests an additional test on the reasonableness of our estimates. If the quantity of currency demanded by US resi-

[20] As noted elsewhere in this analysis, emissions-to-receipts data exist in machine-readable databases beginning January 1974. Data for before 1974 were collected by hand from microfilm. Although data exist prior to 1969, anomolies in the data suggest that the data are unreliable before 1969.
[21] As with the $100 Federal Reserve notes, this estimate is robust to the benchmark assumption. Since the total value of $50 Federal Reserve notes held by the public at that time was only 4.19 billion dollars, even if fifty percent of the stock of such notes at that time were held abroad, which seems unlikely, the additional accumulation of estimated exports of $50 notes would increase the fraction of total currency held abroad by less than one percent.
[22] Simple monthly percentage change at annual rate.
[23] Because of the major shifts in level, the foreign currency data are not directly seasonally adjusted but rather are obtained as the difference between total and domestic currency, each seasonally adjusted. This perhaps also contributes some residual seasonality.
[24] We are indebted to Richard Porter for this interpretation of the data.

dents is seasonal while the quantity demanded by foreign residents is not, then changes in the amplitude of seasonal factors should be correlated with changes in the foreign-held proportion of US currency. A well-estimated domestic currency component should, perhaps, display relatively constant monthly fluctuations. Currency seasonal factors are shown in Figure 11; the upper panel shows the seasonal adjustment factor for the total currency component of M1 as published by the Board of Governors, while the lower panel shows a factor for our domestic currency estimated via X11 (with standard defaults). The amplitude of the seasonal factor for all currency decreases rapidly during the latter part of sample, presumably reflecting the increasing share of U.S. currency in continual circulation abroad. In contrast, the estimated seasonal fluctuations in domestic currency display a near-constant amplitude. During the 1990s, when large currency outflows are alleged to have significantly changed the estimated seasonal factors for total currency (Porter and Judson, 1996), the estimated factors for our domestic currency are essentially the same as those in the late 1960 and early 1970s.

Separating the domestic and foreign components of U.S. currency growth has a significant impact. In recent years, foreign currency shipments have accounted for a large part of monthly fluctuations in currency growth. The recent slowdown of foreign shipments and acceleration of domestic currency growth also are apparent.

3. Comparison to Other Estimates

In this section, we compare our estimates first to those obtained by Porter and Judson (1996), and next to those currently published in the Flow of Funds and the National Income and Product Accounts.

A. Median-Flow Estimates of Porter and Judson (1996)

In the most extensive published analysis, Porter and Judson (1996) examine eleven different methods to estimate the net outflow of currency from the U.S. into foreign circulation during 1977–95. Conditional on a benchmark assumption that at the end of 1976 about half of US currency was foreign-held, their estimated outflows suggest that, at the end of 1995, about 55 percent of the total stock of U.S. currency held by the nonbank public was held abroad, 44 percent of which was in the form of $100 notes (Porter and Judson, 1996, p. 895-6; Table 5).

In the introduction, we noted several reasons why Porter and Judson's median-flow method estimates are not satisfactory for constructing a domestic adjusted monetary base, nor any other domestic monetary aggregate. In this section, we expand our concerns regarding, their

assumed benchmark. Although a benchmark assumption is necessary to construct any estimate of foreign-held stocks from flows, their choice is inappropriate: Absent direct data on the stock of foreign-held currency during any potential benchmark period, the only satisfactory benchmark is a period sufficiently early in time so that one may reasonably assume that the foreign-held stock was approximately zero. Their benchmark does not satisfy this criterion.[25]

To compare our estimated monthly net flows into foreign circulation to the annual flows reported by Porter-Judson (for the shorter time span 1977–95), we sum our monthly flows from December to December. These annual flows, and Porter and Judson's preferred "median-flow" estimates, are shown in Figure 12.[26] Through 1988, our estimates of the amount of currency exported annually are always larger than the median flow estimates of Porter and Judson; in the 1990's their amounts are larger than ours. Nevertheless, the two series tend to move together quite closely. Although the estimated flows differ somewhat, year-to-year accelerations and decelerations are quite close. The largest exception is 1994–5, where our data show a much more rapid decrease in the rate of currency exports than is shown by the Porter-Judson data.

Estimating the *stock* of US currency held abroad is a more subtle matter than estimating outflows. In their article, Porter and Judson emphasize that their preferred median-flow method suggests a foreign-held share of 55 percent, as of December 1995. But, like all stock estimates, this estimate is conditional on the selected initial benchmark. Lacking a direct measure, Porter and Judson consider two polar-opposite alternatives, as of December 1976: First, that no U.S. currency was held abroad and, second, that *all* US currency in circulation outside banks was held abroad. When combined with their median-flow estimates, these alternative benchmarks imply two time series of the implied shares of US currency held abroad during 1977–95. Porter and Judson select the mid-point between these series, shown in Figure 13. Note that Porter and Judson's benchmark produces estimated foreign-held shares for 1977-95 that are approximately the same as *assuming* that half of the outstanding U.S. currency stock has been held abroad each year since 1977.

We find estimates based on Porter and Judson's benchmark implausible, for two reasons. First, both anectodal evidence and domestic surveys suggest that foreign holders prefer large de-

[25] Porter and Judson's analysis is discussed more fully in a separate appendix, available on request from the authors of this paper.

26 Porter and Judson (1996), Table 6. For each year, the median-flow estimate is the median of the flows suggested by Porter and Judson's ten estimators.

nomination notes, while domestic residents hold relatively few such notes.[27] In December 1976, $81.0 billion in US currency was in circulation outside depository institutions, of which 32 percent was $100 notes ($26.7 billion) and 11 percent was $50 notes ($9.0 billion); by December 1995, $376.2 billion was in circulation, of which 64 percent was $100 notes ($241.5 billion) and 12 percent was $50 notes ($46.4 billion). Hence, during the period studied by Porter and Judson, large denomination notes increased *four times* as rapidly as the sum of all smaller denominations, and almost doubled their share of currency held by the nonbank public. Yet, Porter and Judson's estimated share of US currency held abroad *decreases* throughout the 1980s, and is only slightly larger in December 1995 than in December 1976.[28] Second, consider the problem of algebraically accounting for the half of currency in circulation as of December 1976, or $40.5 billion, that Porter and Judson assume was held abroad. This amount, at that time, would equal the sum of all $100 and $50 notes in circulation, plus about one-sixth of all $20 notes. Alternatively, if domestic residents are assumed to have held one-fourth of $100 and $50 notes, the amount would encompass half of all the $20 notes in circulation, in addition to the remaining three-quarters of $100 and $50 notes. Such high proportions seem improbable, given anecdotal evidence and the extensive shipments of large-denomination currency from the US during the late 1980s and early 1990s. [29]

In contrast to Porter and Judson, we construct stocks of foreign-held US currency by accumulating our estimated net outflows of $100 and $50 notes from an assumed benchmark amount of zero, beginning, respectively, in December 1964 and December 1968.[30] Although some US currency certainly was foreign-held on these dates, our stock estimates are nevertheless robust to our benchmark assumption. In December 1964, the total value of $100 and $50 notes in circulation was $11.8 billion (versus $35.7 billion in December 1976). Even if half, rather than zero, of these notes had been held abroad—which seems unlikely—the effect on our esti-

[27] This evidence is surveyed by Porter and Judson (1996). Bach (1997, p.49) notes that "…a 1995 survey of U.S. households found that they could account for at most a little more than 3 percent of total holdings of $100 notes."

[28] In one method that extends back in time to earlier years, Porter and Judson note that their seasonal method suggests that 40 percent of U.S. currency was held abroad as early as 1960. We find this estimate also implausible. Total currency held by the nonbank public in January 1960 was $28.7 billion. Forty percent of this total is a dollar amount equal to the sum of all $50 and $100 notes in circulation plus half of the $20 notes. See *Banking and Monetary Statistics 1941-1970*, p. 625.

[29] This analysis suggests an alternative benchmark, not considered by Porter and Judson: select the midpoint between the shares implied by zero or all $100 notes held abroad. This alternative suggests that 16.5 percent of currency was abroad as of December 1976 (total currency in circulation outside banks as of December 1976 was $81 billion, of which $26.7 billion was in $100 notes).

mated foreign-held stock is minimal: by December 1995, the share of US currency held abroad increases by less than 2 percent, relative to our estimated 52 percent. The robustness is a direct result of using a benchmark date sufficiently early so that the amounts of $100 and $50 notes in circulation are small, relative to subsequent issuance.

In summary, for flows of currency to foreign circulation, our method relative to Porter and Judson (1996) suggests relatively larger outflows during the 1970s and most of the 1980s, about the same annual outflows during the late 1980s and early 1990s, and significantly slower currency outflows during the mid-1990s. For the foreign-held stock of US currency, we estimate that in 1977 about one-sixth of US currency was held abroad, versus Porter and Judson's assumption of one-half; during the 1980s, we estimate that the foreign-held share increased almost continuously, while the Porter and Judson estimate that the proportion *decreased* up to about 1989; during the 1990s, we find a much sharper slowing of foreign demand for U.S. currency than is reported in Porter and Judson. At the end of Porter and Judson's sample period, our estimates are remarkably close to theirs, despite difference in estimation methods. Porter and Judson estimate that foreign holdings of U.S. currency were about 55 percent of the total currency held by the nonbank public in December 1995; our estimate, based on $50 and $100 notes, is 53.2 percent. Of their 55 percent, Porter and Judson estimate that 44 percentage points was accounted for by $100 notes; we estimate 46 percent.[31] For $100 notes alone, Porter and Judson estimate that 74 percent of outstanding $100 notes were held abroad at the end of 1995; accumulating our estimated emissions of $100 notes to foreign circulation since December 1964 suggests 72 percent.

B. The Shipments Proxy: Feige (1994, 1996), Survey of Current Business , and Flow of Funds Accounts

Feige (1994, 1996) also constructed estimates of the fraction of U.S. currency held abroad. Among his various methods is the *shipments proxy*.[32] In that method, he assumes that the entire net outflow of $100 Federal Reserve notes from the New York City cash office is ex-

[30] These dates are pragmatically chosen as the earliest for which suitable currency processing data are available.

[31] Porter and Judson do not attribute to any specific denomination the 11 percentage points not accounted for by $100 notes. Our examination of $50 notes suggests that about an additional 7.2 percentage points may be accounted for by foreign holdings of $50 notes.

[32] The shipments proxy also is among the methods considered by Porter and Judson. Although their article does not include enough detail to permit a direct comparison, in private correspondence Richard Porter indicated that the correlation between their median-flow and shipment proxy's estimates (applied solely to New York City data) is approximately 0.97.

ported and remains in continual circulation outside of the U.S., and that such exports from New York are the sole source of currency leaving the country.[33] In notation similar to that introduced in section 2, the foreign-held stock of US currency is obtained by accumulating the net emissions ($E_t^{L,NYC} - R_t^{L,NYC}$) of $100 notes from the New York City cash office.

The estimated flows of US currency to foreign circulation that were introduced into the Flow of Funds and the National Income and Product Accounts during the latter half of 1997 are based on the shipments proxy, except that data from both the New York City and Los Angeles cash offices are included, beginning January 1974. Estimates of the stocks of foreign-held US currency are obtained by accumulating the net quarterly flows from a benchmark which assumes that the foreign-held stock was 49.2 percent of total US currency in circulation as of December 1973.[34]

Overall, these more recent annual flow estimates are very similar to Porter and Judson's median-flow estimates (Figure 12); our concerns regarding the latter apply to the former. The close correlation between the two sets of estimates is not mysterious, for two reasons. First, prior to 1990, emissions and receipts of $100 notes at the Los Angeles cash office were approximately equal, and net outflows from the office were small. Only during the second half of 1991 did these begin to diverge, when the Los Angeles cash office began receiving considerably more $100 notes than it emits to depository institutions, a situation that persists. The reasons for this change are uncertain: perhaps the notes came (and are coming) from the Far East, or perhaps from underground economic activity along the Mexican border. Alternatively, the change might represent a shift of some activity to Los Angeles from other cash offices: the relative growth of note receipts at the New York City cash office slowed during this period, for example. Regardless of the reason, we emphasize that the estimates presented in this analysis are based on the emissions and receipts of large denomination Federal Reserve notes at all 37 Federal Reserve cash offices, not just two, and hence are likely much more robust to such events.

The stock of foreign-held US currency suggested by the shipments-proxy method, expressed as a share of US currency in circulation outside banks, is compared to other estimates in Figure 13. Due to the benchmark assumption that half of US currency was held abroad as of December 1973, the shipments proxy method, like Porter and Judson's median-flow method, is ap-

[33] Feige's method is discussed more fully in an appendix available on request from the authors.

[34] Bach (1997), Table 3, page 49. No explanation is offered for how the benchmark foreign-held percentage was obtained.

proximately equivalent to *assuming* that half of US currency has been held abroad each year since 1974. The two methods share another characteristic: except for a small increase circa 1980, the estimated shares both decrease during most of the 1980s, even while large denomination notes are growing four-fold faster than small denominations (thereby doubling their share of currency in circulation), and surveys suggest that US households are not increasing their holdings of large denomination notes.

4. The Domestic Adjusted Monetary Base and Monetary Policy

In this section, we discuss how our partition of domestically and foreign-held currency may be used to build a domestic adjusted monetary base data series. We use the adjusted monetary base as published by the Federal Reserve Bank of St. Louis, because all the required data are readily available.[35] This measure of the adjusted monetary base has been recently revised, and is now constructed as a chain index; see Anderson and Rasche (1996 a, b). During each of several separate intervals, the adjusted monetary base is constructed by adding a reserve adjustment magnitude, or RAM, to the monetary source base. Different, specific RAM series are used in each interval. The final adjusted monetary base is formed by chaining the separate pieces together to form a single continuous time series. [36]

Our separation of currency enters via the monetary source base, which is defined as the sum of currency in circulation outside the Federal Reserve and the Treasury, plus the deposits of domestic depository institutions at Federal Reserve Banks.[37] The *domestic* monetary source base equals the monetary source base minus the estimated amount of foreign-held currency. We have calculated this measure of the domestic monetary source base monthly from January 1950 through August 1999.[38] The overall domestic adjusted monetary base is constructed by adding, during each time interval, the domestic monetary source base plus the appropriate RAM adjust-

[35] So far as we could discover, the data necessary to reproduce the Board of Governors adjustment for changes in reserve requirements has never published.

[36] The St. Louis adjusted monetary base is chained, or spliced, in 1972, 1975, and 1980, and seasonally adjusted by X11-ARIMA.

[37] Note that the Federal Reserve Bank deposits included in the monetary source base already reflect a separation of domestic and foreign components. Deposits due to depository institutions doing business in the U.S. (including branches and agencies of foreign banks) are included, but deposits due to foreign central banks are excluded. (No other offshore depository institutions except central banks hold deposits at the Federal Reserve.)

[38] Before 1965, the domestic and total monetary source base are the same; we choose 1950 because that is the first date for which the St. Louis Fed publishes a seasonally adjusted, adjusted monetary base. Data on the total monetary source base are available from the St. Louis Federal Reserve Bank beginning in 1917.

ment; the final series is chained together in the same manner as the total St. Louis adjusted monetary base.

The total and domestic adjusted monetary base measures are shown in Figure 14. The difference between them increases steadily after 1965, for two reasons: an increasing share of currency is being held abroad, and currency is becoming a larger share of the source base. Year-over-year growth rates of the total and domestic adjusted base are shown in Figure 15. Currency exports have frequently accounted for three or more percentage points of growth in the adjusted monetary base during the sample period. In recent years, our estimates suggest very slow currency outflows and small differences in their growth rates.

5. Domestic monetary aggregates, the k ratio, and velocity

Beyond the adjusted monetary base, outflows of U.S. currency to foreign circulation have been large enough to distort inferences regarding the stance of monetary policy based on broader monetary aggregates. Year-over-year growth rates of total (published) and domestic M1 and M2 are shown in Figures 16 and 17.[39] Growth rates of the published data for both aggregates are significantly larger than those of their domestic counterparts during the mid-1970s and the late 1980s, through 1990. For both M1 and M2, the extent of the secular deceleration of money growth since the mid-1980s has been partially masked, in published data, by the acceleration of currency exports, especially between 1987 and 1990. In contrast to shipments proxy-based methods (not shown on these figures), our estimates suggest that currency exports have slowed significantly since 1995, and that increased currency growth during recent years reflects strong domestic economic activity. Finally, we note that, historically, differences between the growth rates of published and domestic aggregates have tended to *increase* when money growth was *slowing*, a relationship that may prove important in empirical models of the effects of monetary policy.

Exports of currency also have distorted components of money multipliers. The *k* ratio is equal to the ratio of the currency component of M1 divided by transaction deposits.[40] Four measures of the *k* ratio are shown in Figure 18. The upper two lines measure *k* with published

[39] The M1 data shown in the figures have been adjusted by adding the amount of transactions deposits that the Federal Reserve Board estimates is being swept by banks from checking deposits into savings deposits. Note that these retail sweep programs began only in January 1994, and do not include sweeps of checking deposits into repurchase agreements or money market mutual funds. For discussion, see Anderson (1995) and Bennett and Hilton (1997). The data are from the St. Louis Federal Reserve Bank at http://www.stls.frb.org/research/swdata.html.

[40] For discussion of money multipliers and components, see Rasche and Johannes (1986).

total currency in circulation, and with and without, respectively, adding to published transaction deposits the Federal Reserve Board's estimate of the amount of retail sweep programs.[41] The lower two lines measure *k* using domestic, rather than total, currency, and also, respectively, with and without including the amount of retail sweep programs. The bottom line, based on domestic currency holdings and including an adjustment for the amount of transaction deposits swept into savings deposits beginning January 1994, displays remarkable stability around a generally downward sloping trend throughout 1947–99. This behavior of the relative quantities of currency and transaction deposits lends further support to our estimates of foreign-held U.S. currency. Because the *k*-ratio remains close to its mean during the entire 50 year period, reports of the imminent death of currency as a domestic transactions medium perhaps are overstated.

Finally, three measures of the velocity of the adjusted monetary base are shown in Figure 18. The measures published by the Board of Governors and the St. Louis Federal Reserve Bank have very similar behavior. The velocity of both measures increases steadily until 1980, after which it decreases. This behavior clearly reflects the path of short-term interest rates and inflation, and hence the opportunity cost of holding base money. The velocity of the domestic base increases more rapidly than the velocity of the other two measures before 1980. After 1980, however, it becomes stationary, with no discernible trend. This pattern might suggest a higher interest elasticity for domestically held base money, compared to the foreign-held component. At a minimum, it suggests that empirical studies that use the adjusted monetary base must be cautious regarding a break in the trend of velocity circa 1980.

6. Conclusions

U.S. currency held abroad is an important asset for residents of many countries, and a substantial source of revenue to the U.S. Treasury. Exports of U.S. currency during the last several decades have significantly distorted growth rates of the adjusted monetary base and of both narrow and broad monetary aggregates, including M1 and M2. The increase in foreign-held currency also has distorted components of the money multiplier, such as the "k" ratio of currency to checkable deposits, and perhaps lie behind some conclusions regarding the asserted instability of U.S. money demand relationships. Recent revisions to both the Flow of Funds and the National Income and Product Accounts recognize these, and other, aspects of the importance of measuring the amount of U.S. currency held abroad. Further, a partitioning of the monetary base between

[41] See footnote 37. Transactions deposits prior to 1959 are the demand deposit component of the historical M1 series in Rasche (1987).

its domestically and foreign-held components seems necessary if further progress is to be made in empirical models to link the behavior of the economy's price level and the balance sheet of its central bank, the Federal Reserve.

The method of estimation of foreign-held currency proposed in this analysis provides the first consistent monthly measure of the domestic monetary base and foreign-held U.S. currency. Unlike previous analyses, the time series is benchmarked to dates sufficiently early in time (December 1964 and December 1968) that relatively little U.S. currency was held abroad, making our estimates robust to the selected benchmark. Our estimates also permit construction of domestic monetary aggregates, including domestic M1 and M2. The estimates may be readily updated (by Federal Reserve staff) at the close of each month from Federal Reserve currency processing data. Further, because the estimates utilize flows of large denomination Federal Reserve notes from all 37 Federal Reserve cash offices, rather than just New York City and Los Angeles, they should be less sensitive than previous series to shifts in currency processing patterns among cash offices.

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Figure 1: Ratio of Emissions to Receipts at Federal Reserve Cash Offices

monthly, January 1974 - June 1999

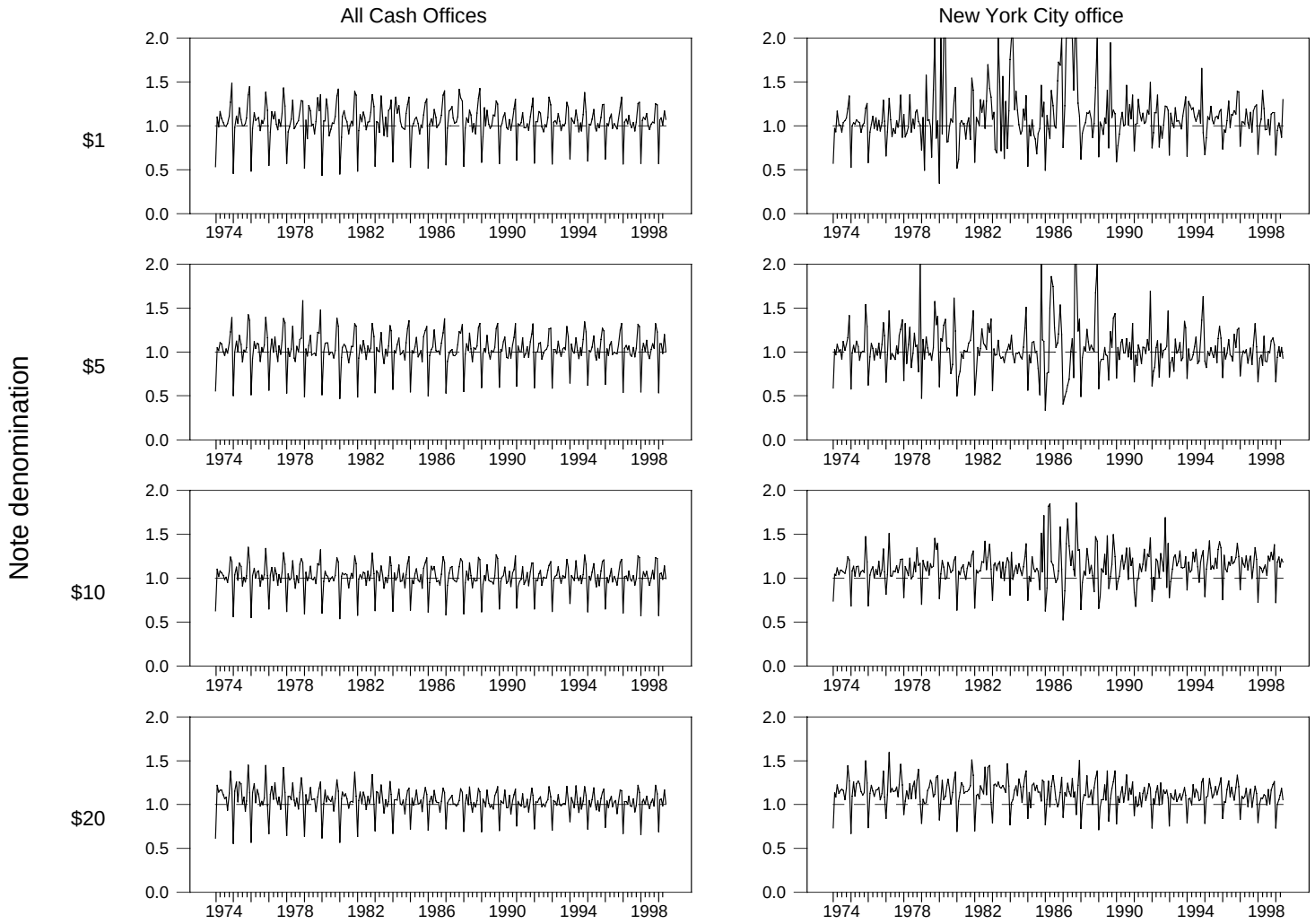


Figure 2: Ratio of Emissions to Receipts, $10 notes

monthly, January 1965 - June 1999 (varying vertical scales)

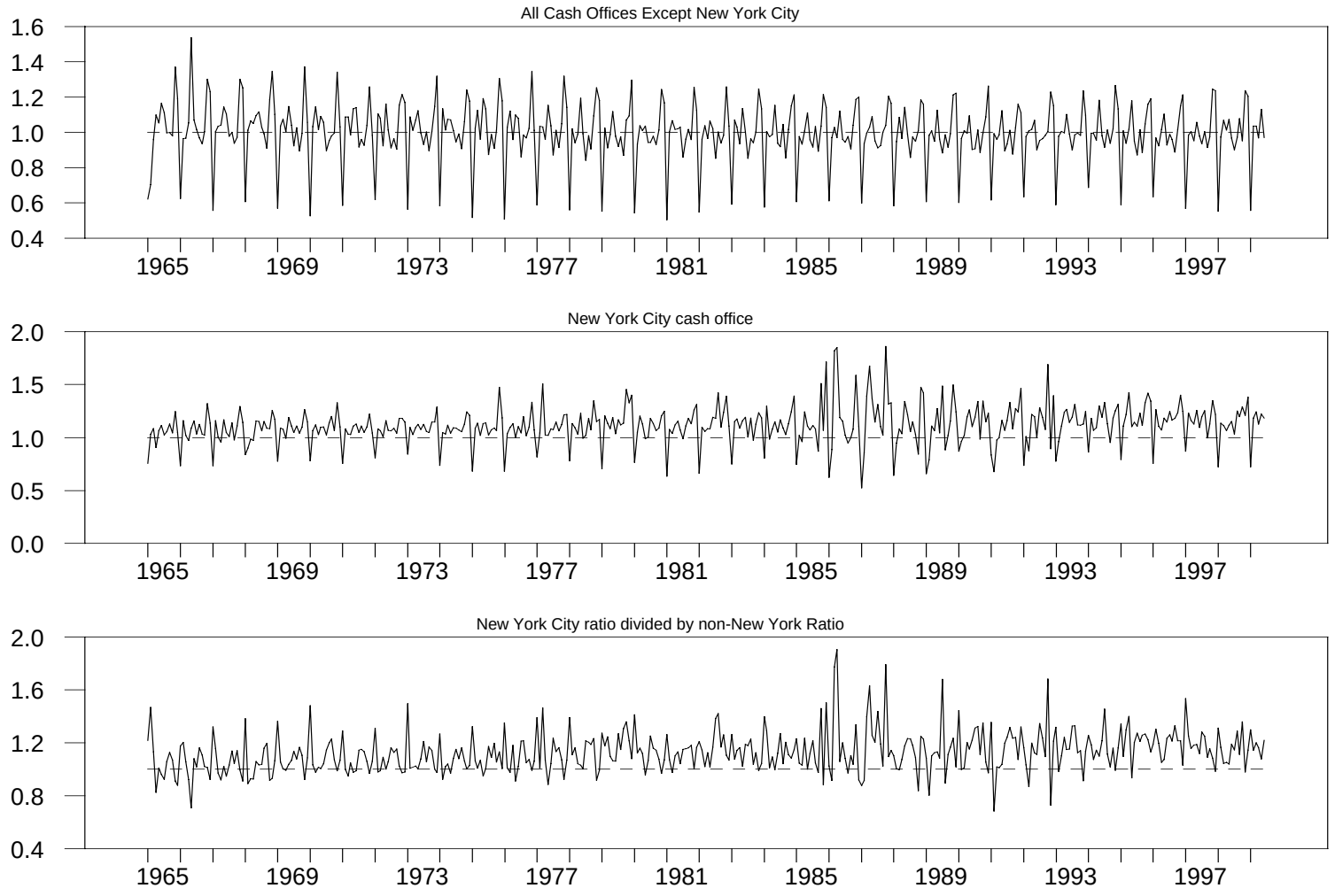


Figure 3: Ratio of Emissions to Receipts at Federal Reserve Cash Offices

monthly, January 1965 - June 1999 (varying vertical scales)

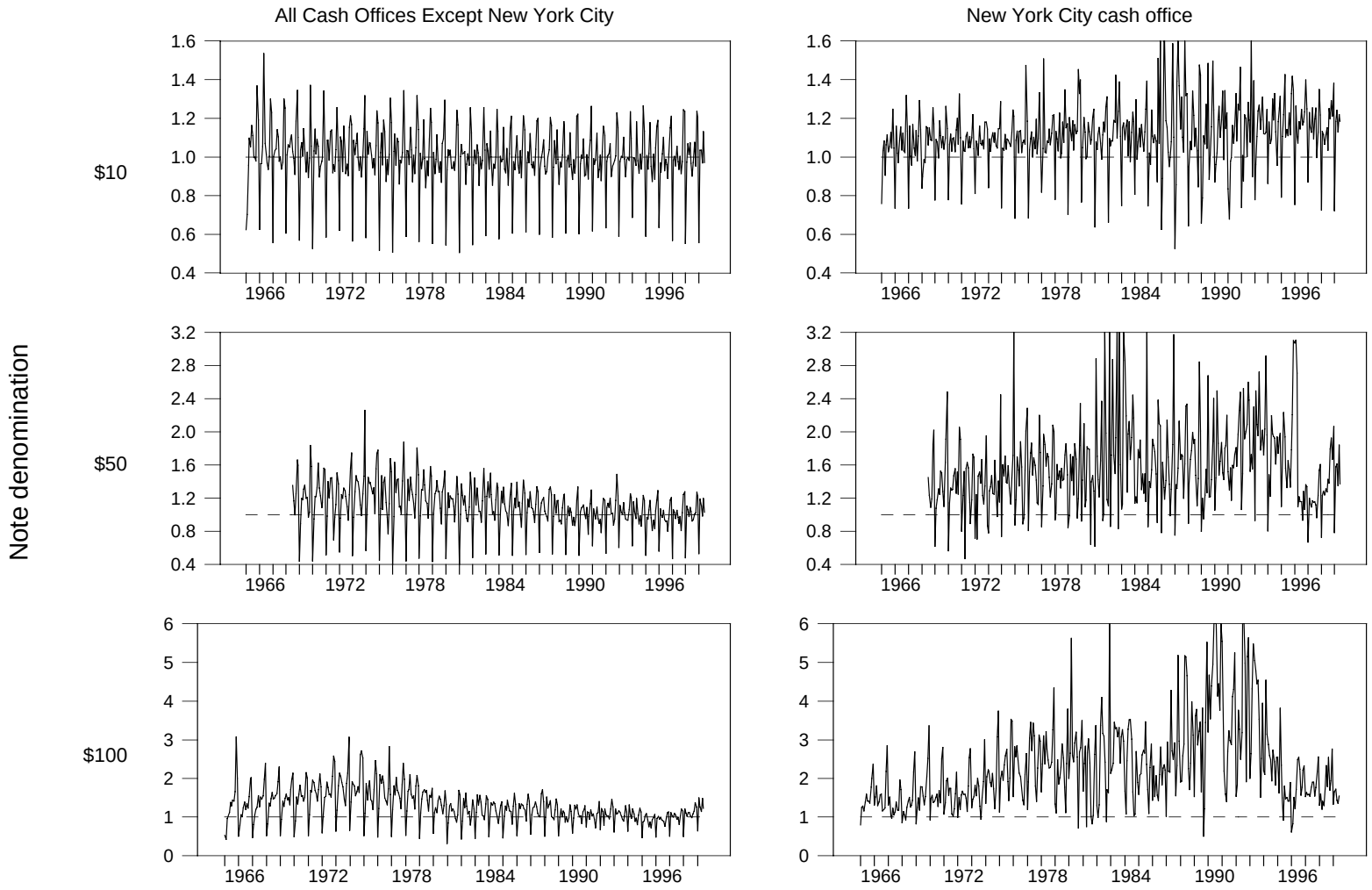


Figure 4: Estimated Domestic Share of $100 notes Shipped

based on circulation pattern of $10 notes

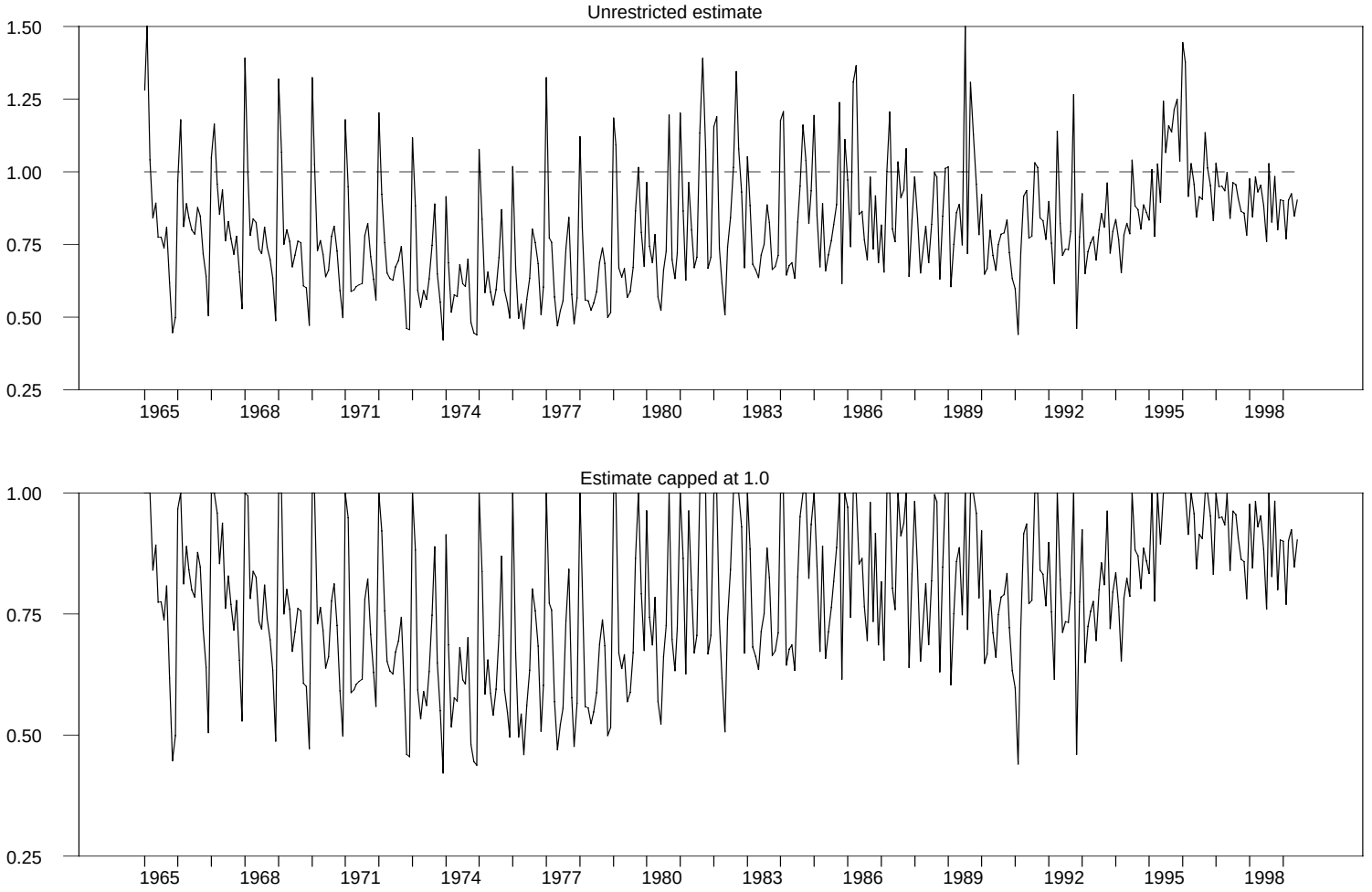
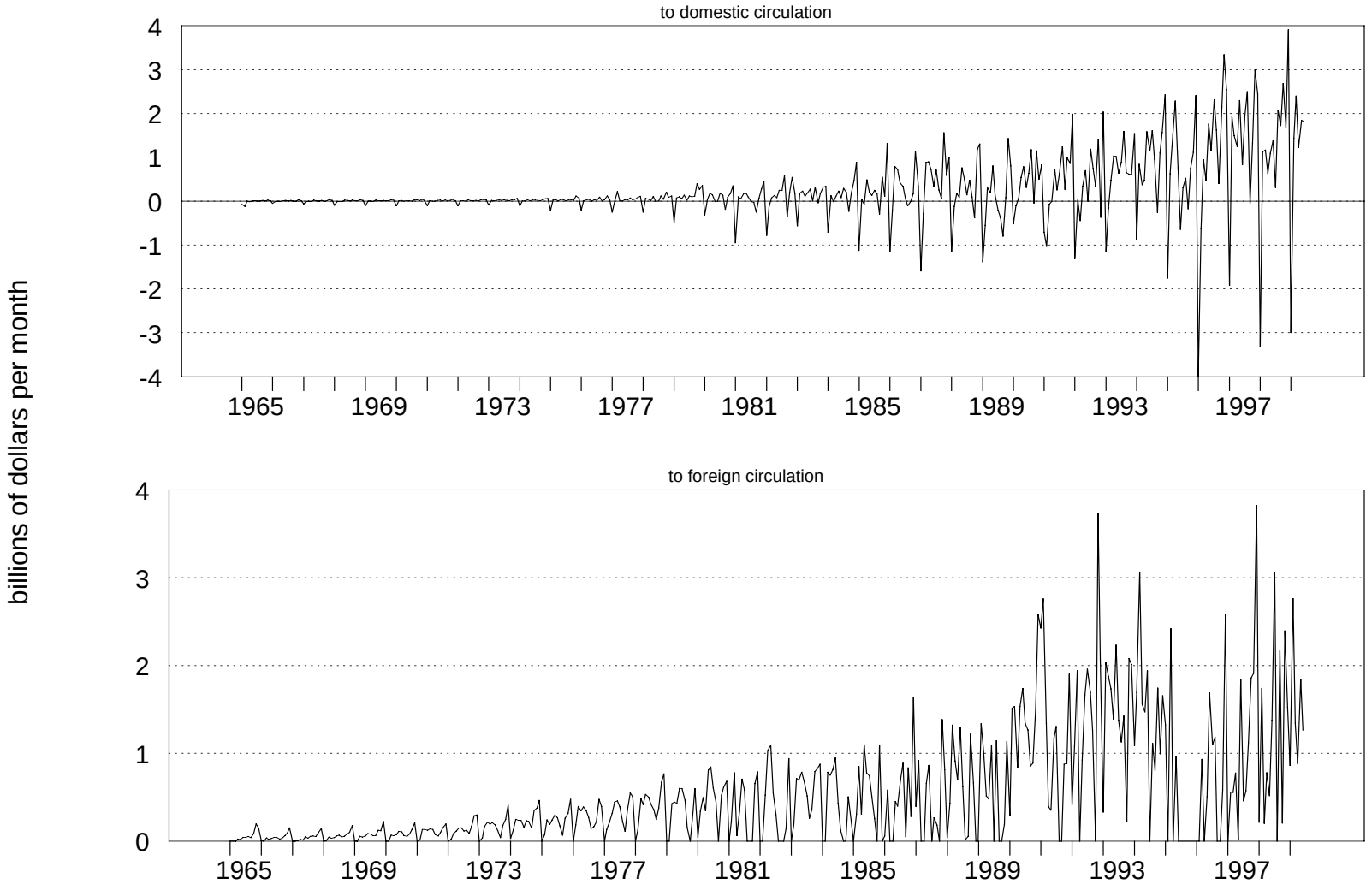


Figure 5: Estimated Net Emissions of $100 notes

Based on New York City cash office data for $10 notes



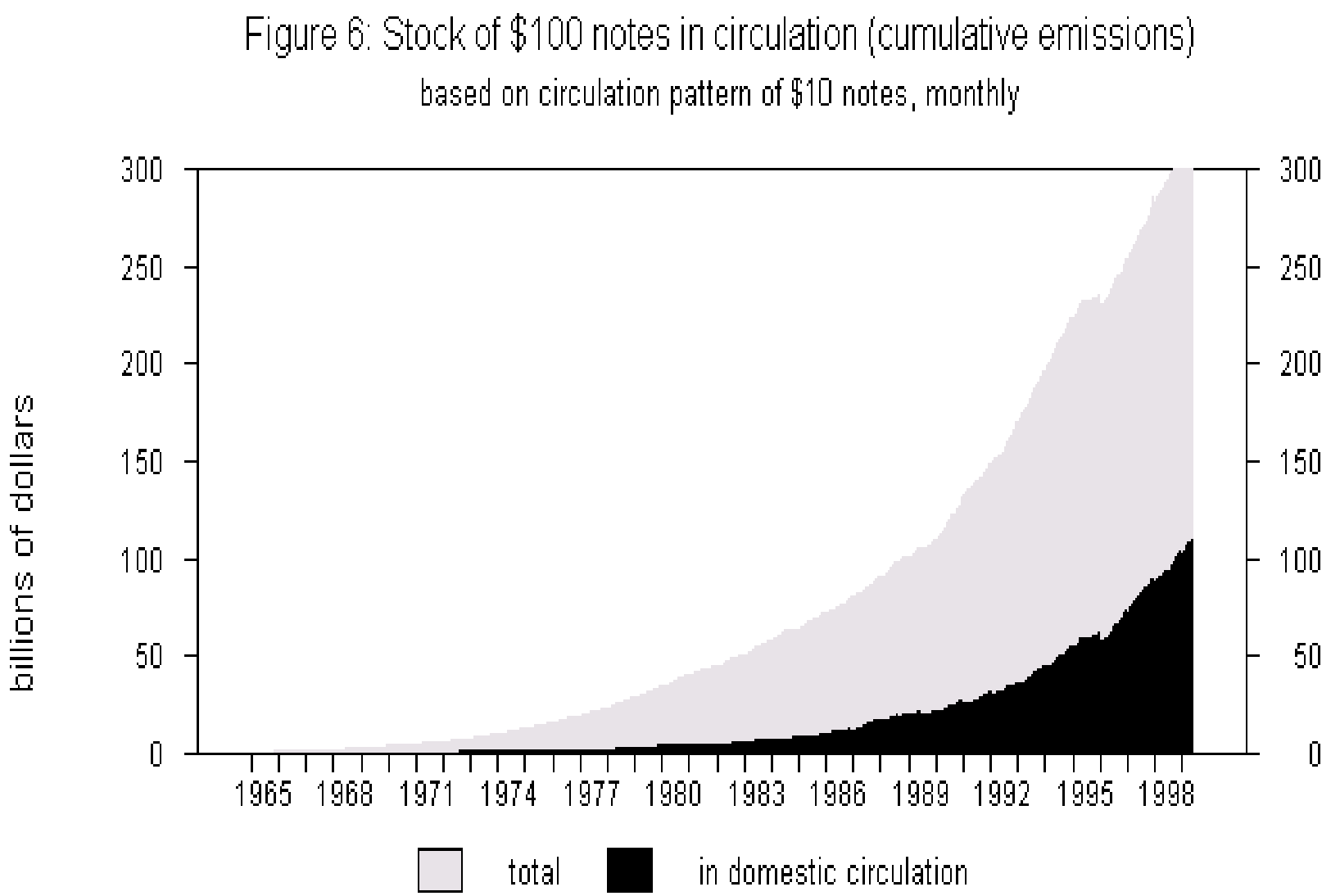


Figure 6: Stock of $100 notes in circulation (cumulative emissions)
based on circulation pattern of $10 notes, monthly
billions of dollars
300
250
200
150
100
50
0
1965
1968
1971
1974
1977
1980
1983
1986
1989
1992
1995
1998
total
in domestic circulation

Figure 7: Estimated Domestic Share of $50 notes Shipped

based on New York City emissions-to-receipts ratio of $10 notes

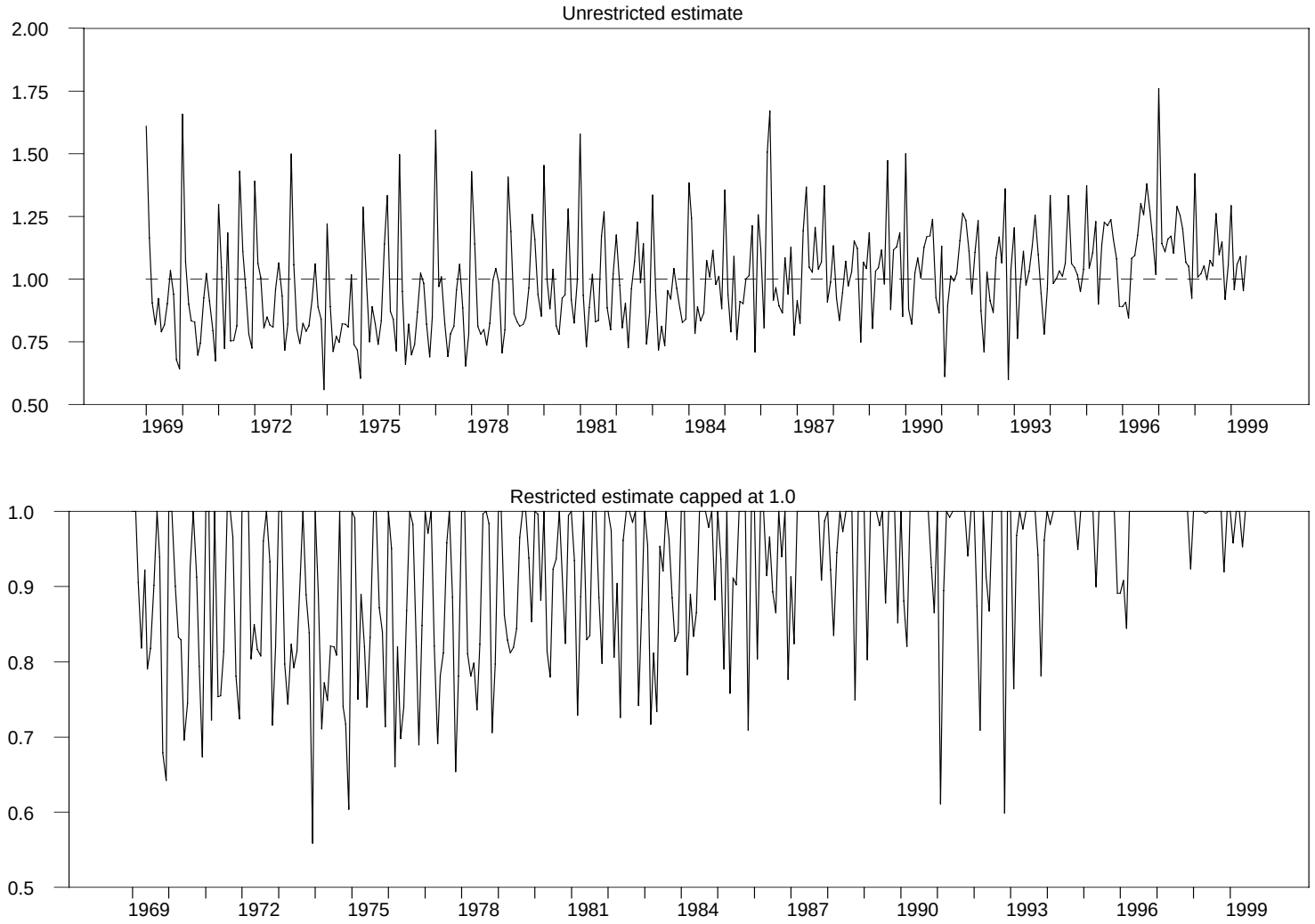
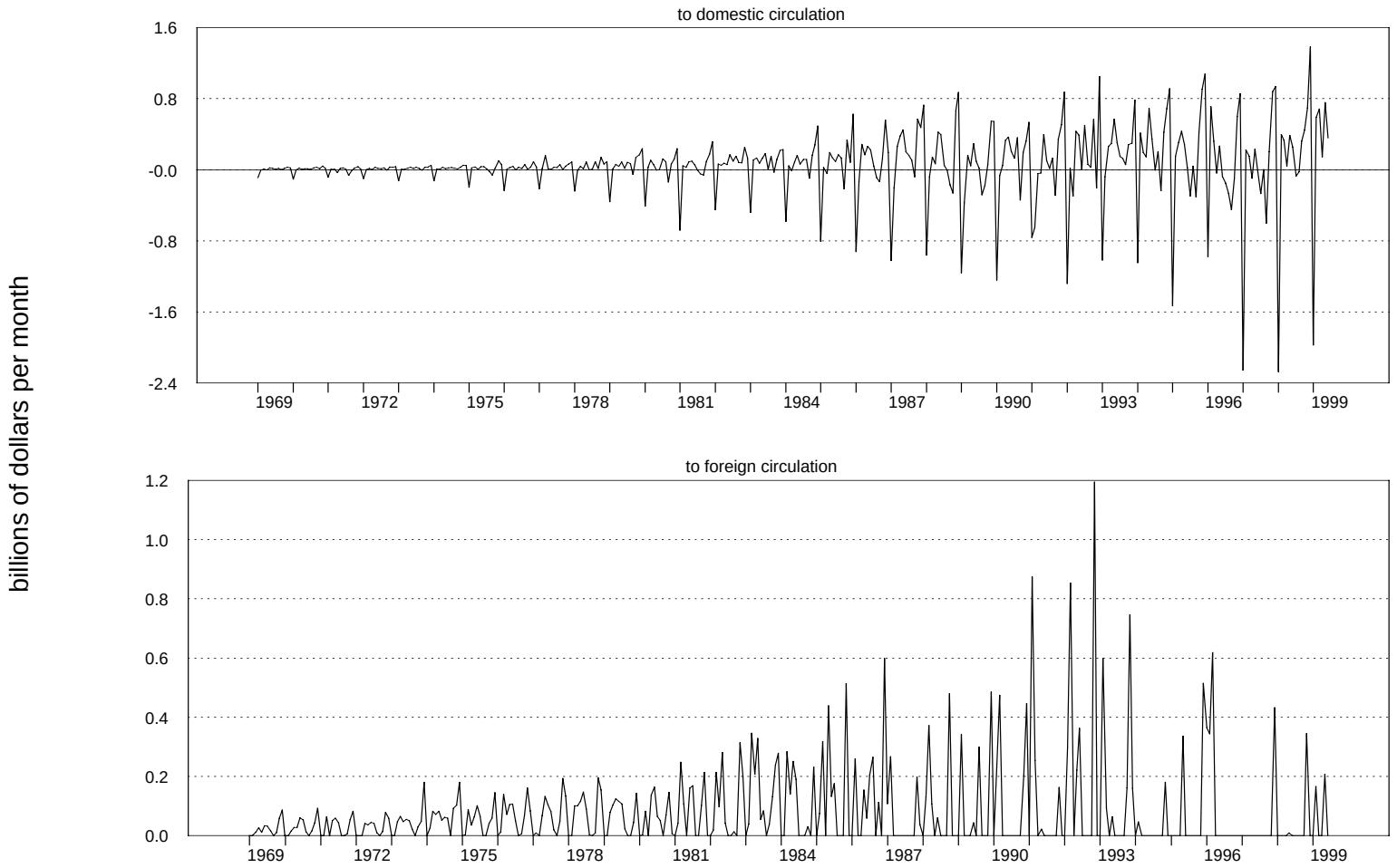


Figure 8: Estimated Net Emissions of $50 Notes

based on New York City cash office data for $10 notes



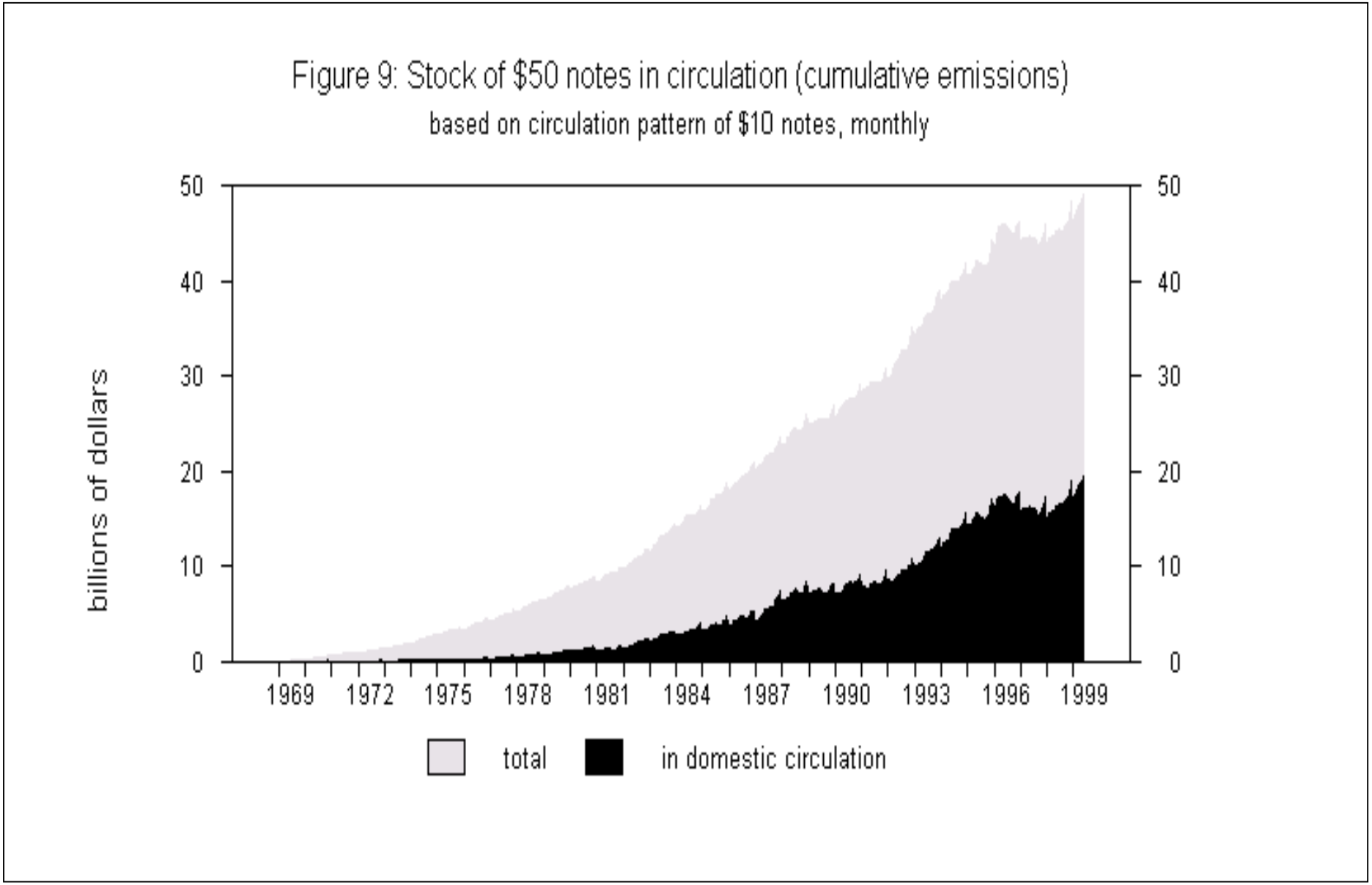


Figure 9: Stock of $50 notes in circulation (cumulative emissions)
based on circulation pattern of $10 notes, monthly
billions of dollars
0
10
20
30
40
50
1969
1972
1975
1978
1981
1984
1987
1990
1993
1996
1999
total
in domestic circulation

Figure 10: Growth Rates of Currency in M1

monthly, seasonally adjusted

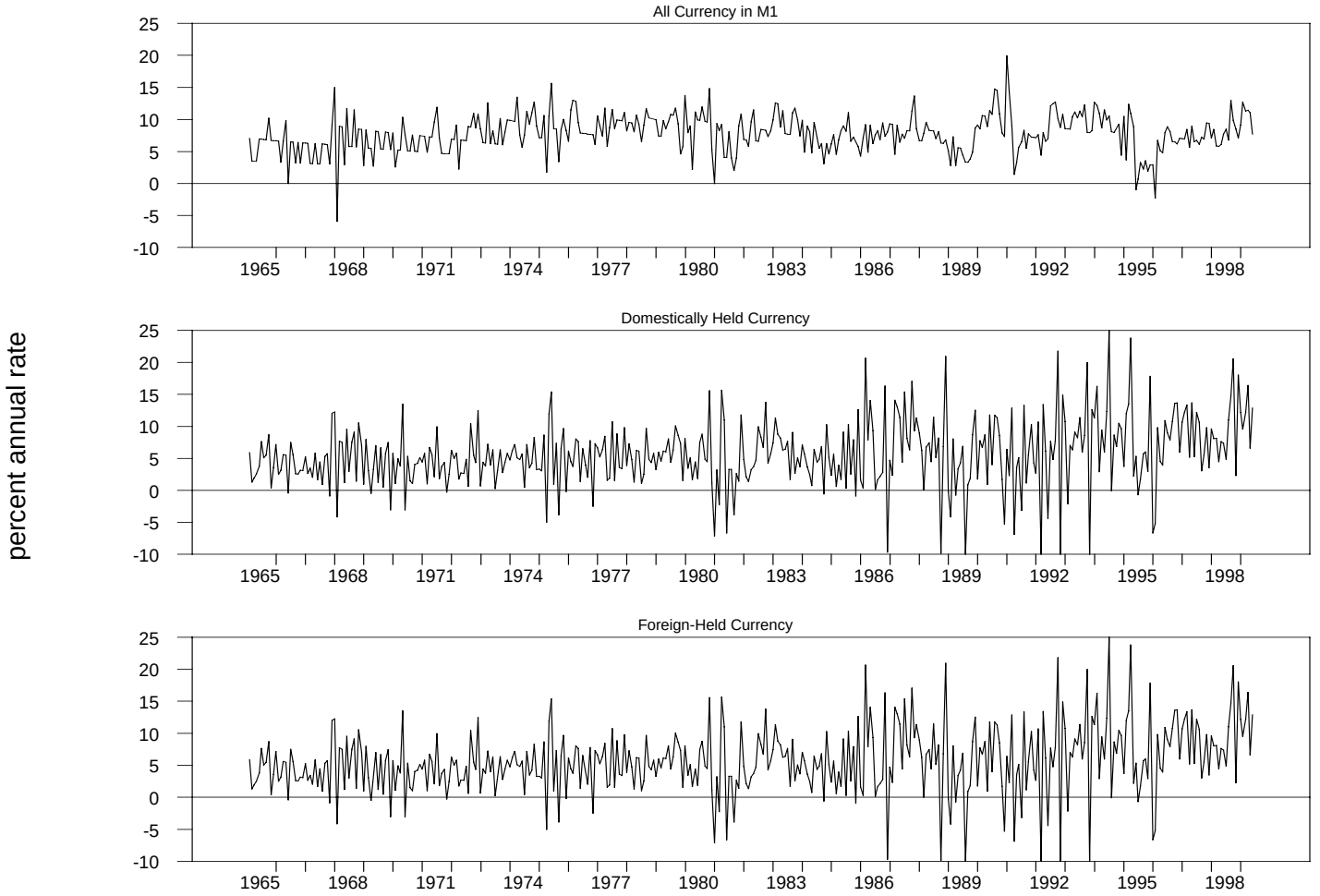


Figure 11: Seasonal Factors for Currency in M1

monthly, January 1965 - June 1999

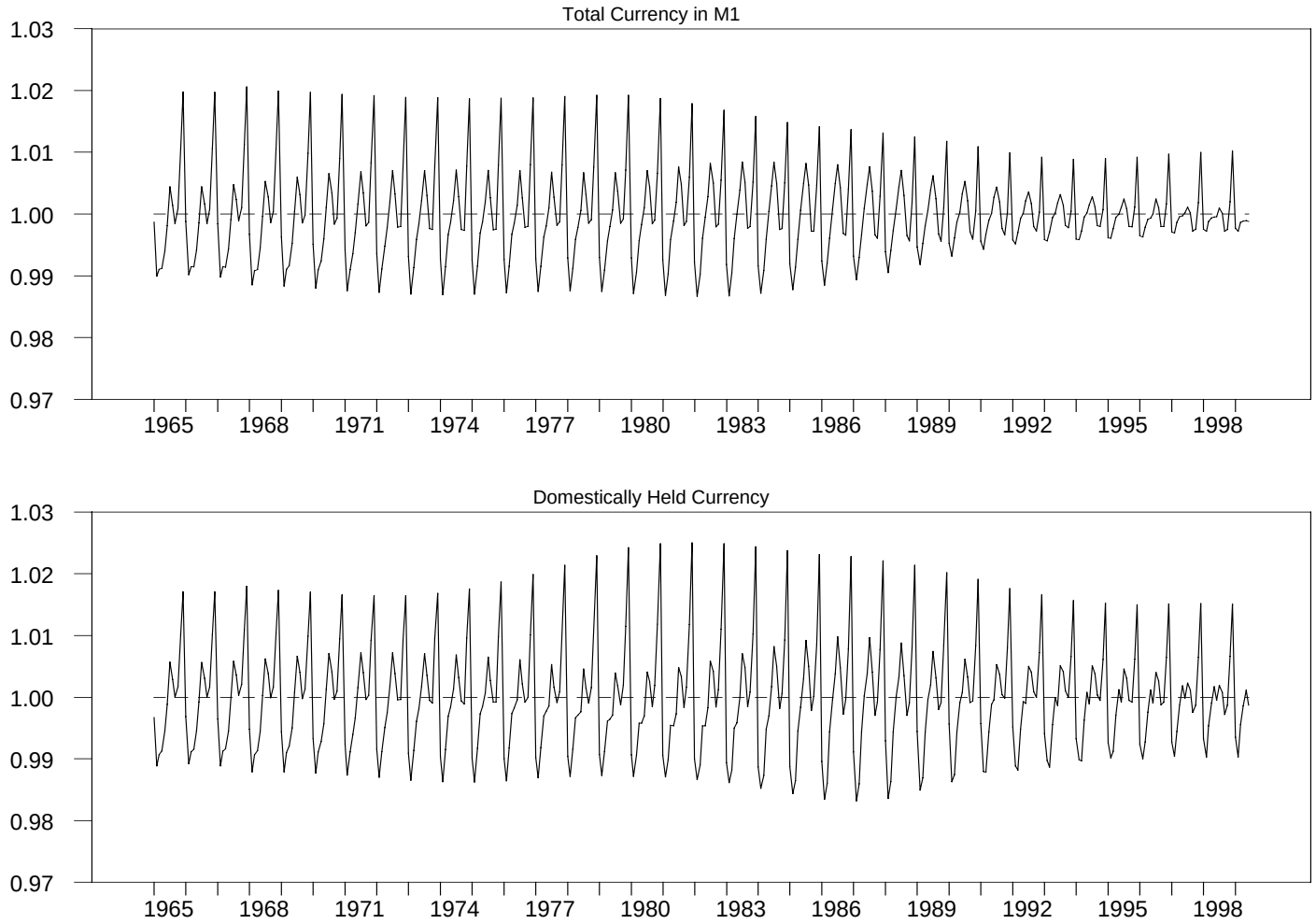


Figure 12: Flow of U.S. Currency to Foreign Circulation

annual flow, billions of dollars, n.s.a.

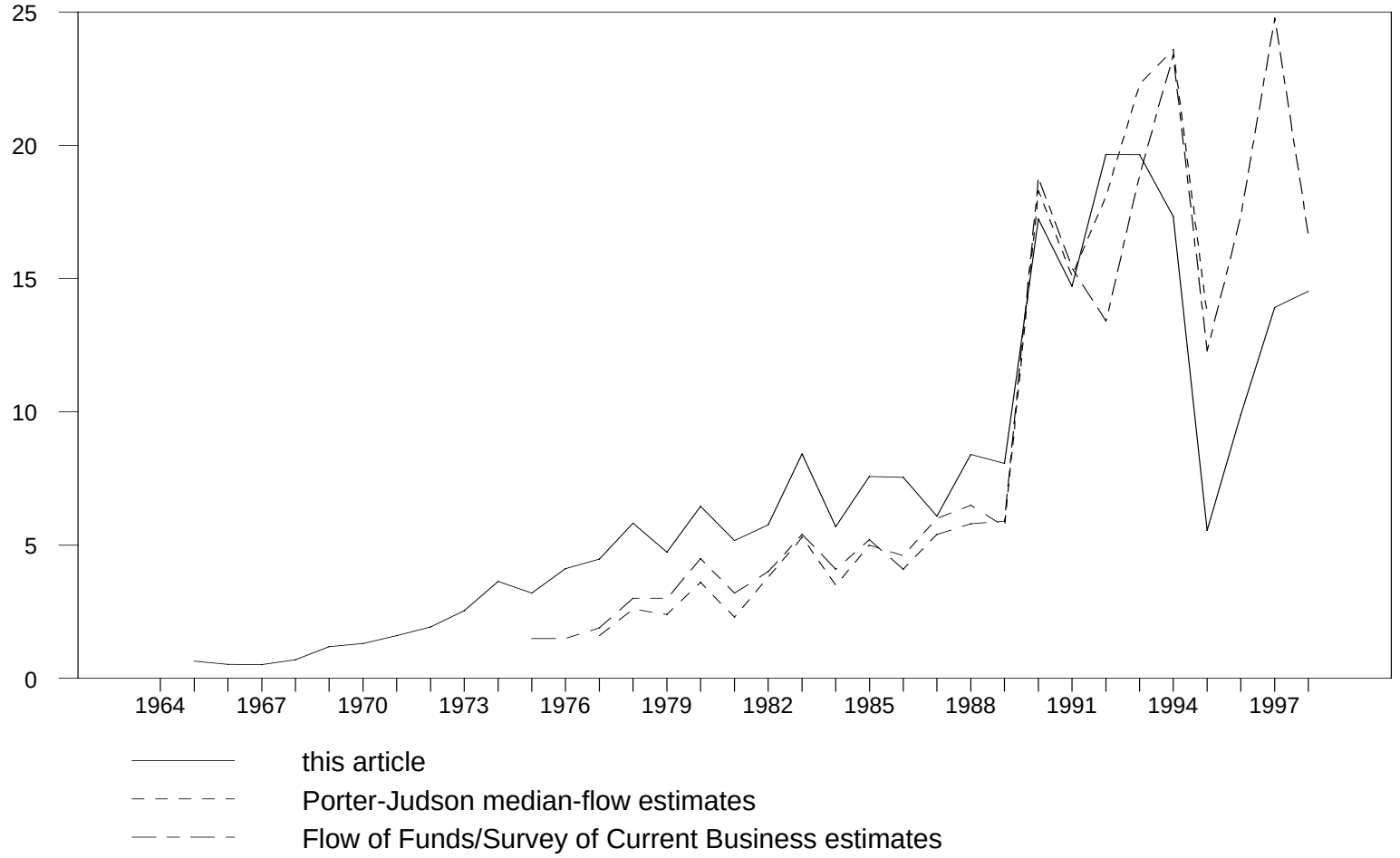


Figure 13: Estimated Share of U.S. Currency Held Abroad 1965-98

annual estimates

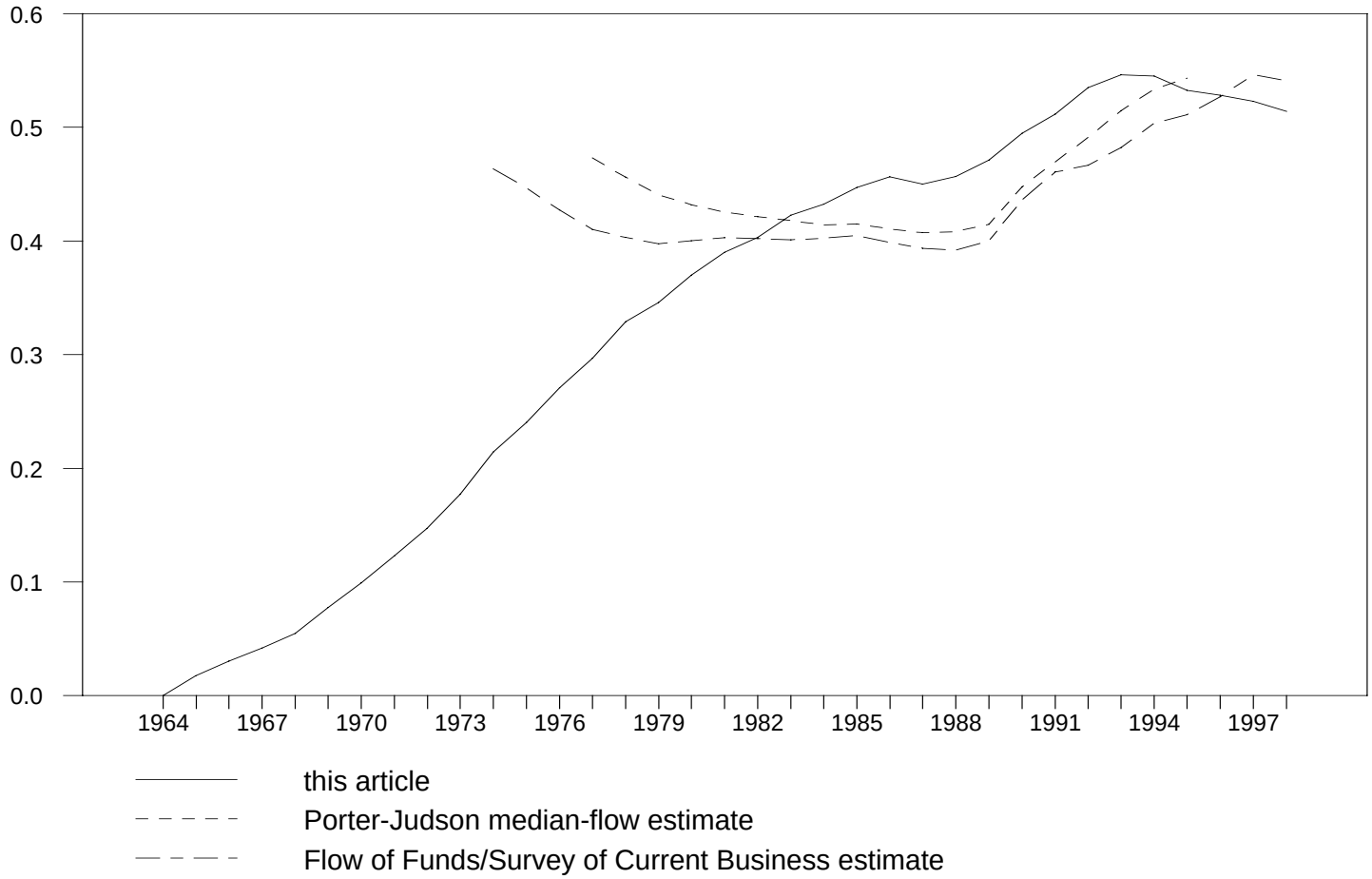


Figure 14: Total and Domestic Adjusted Monetary Base

January 1965 - December 1997

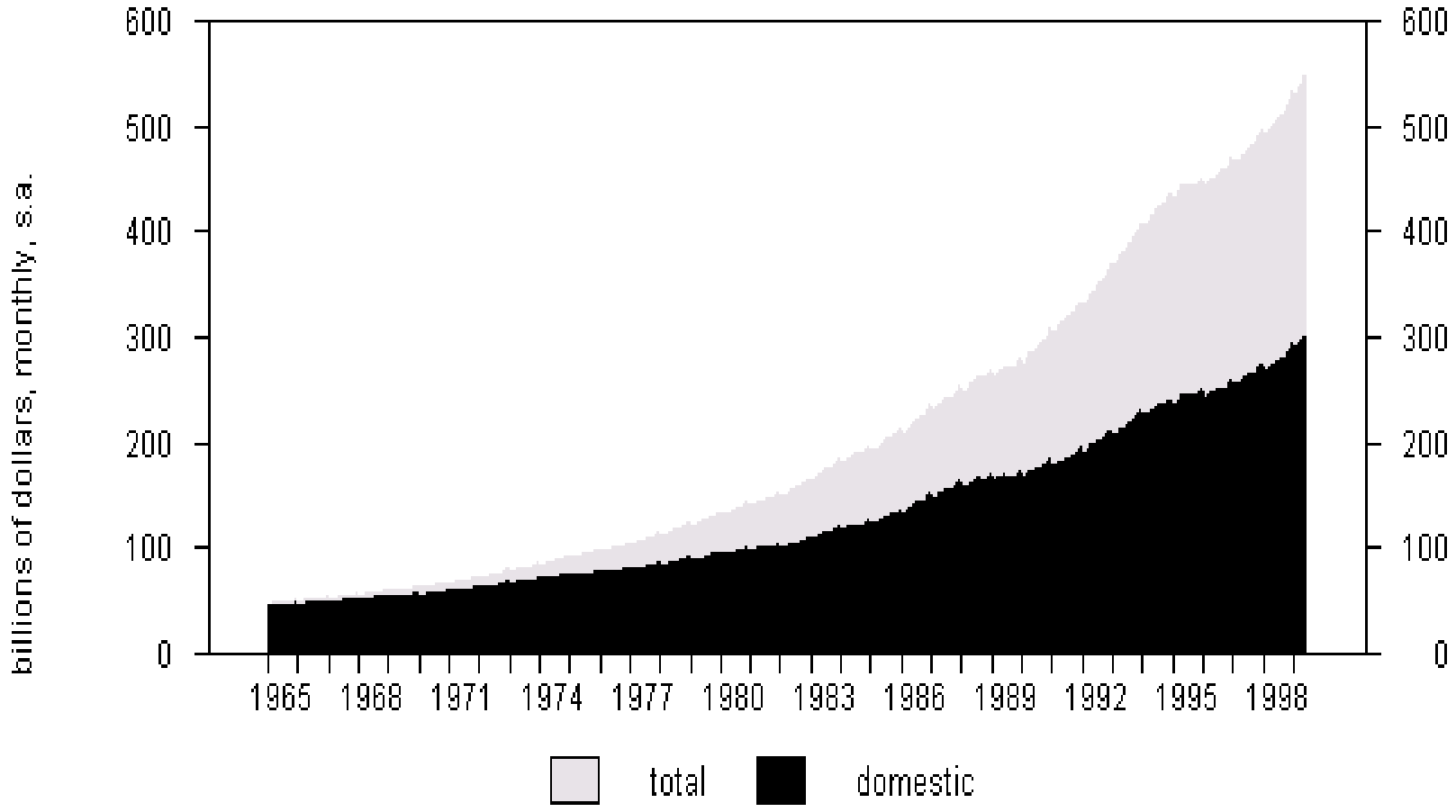


Figure 15: Growth Rates of Total and Domestic Adjusted Monetary Base

change from year ago, monthly, January 1965 - June 1999

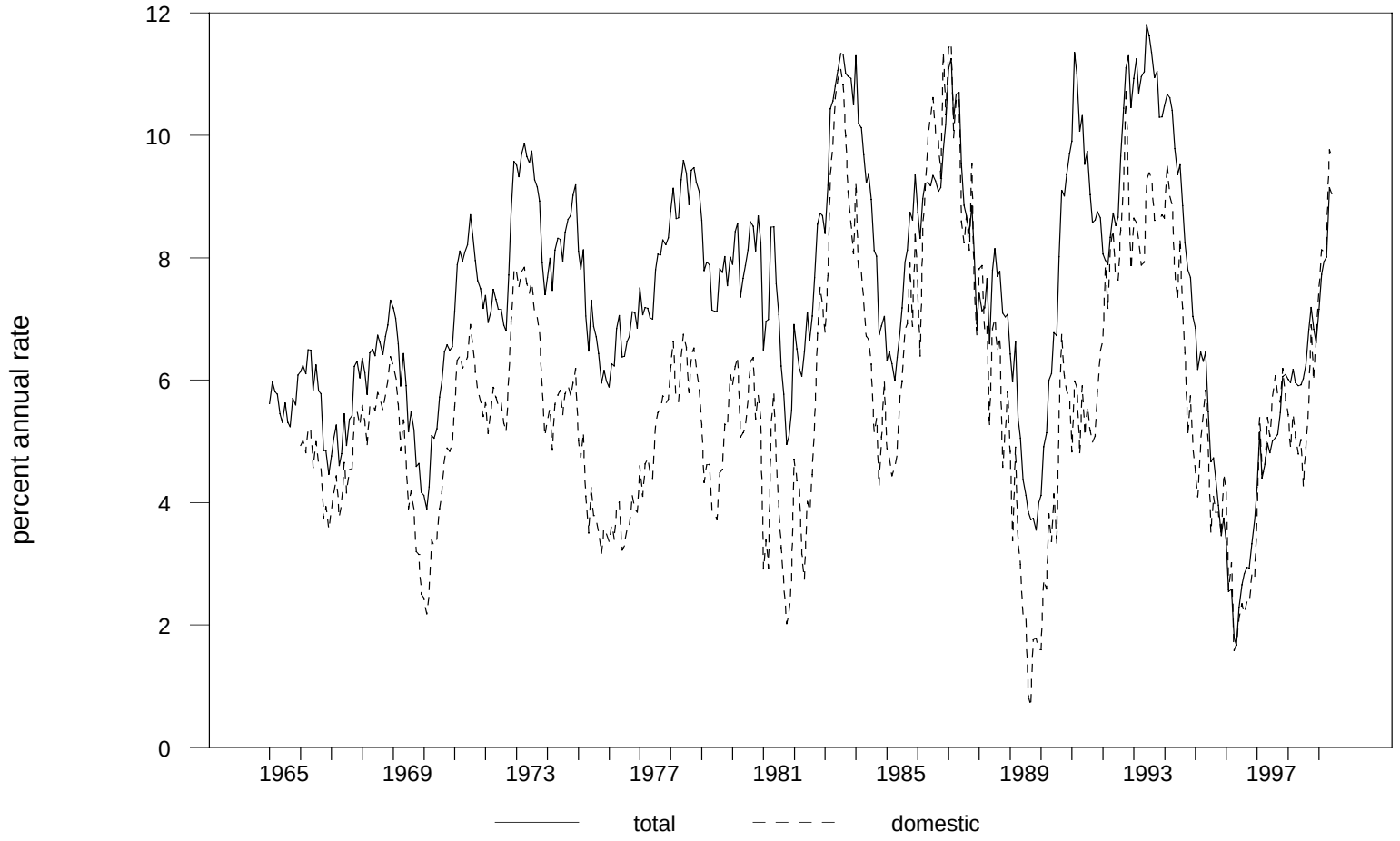


Figure 16: Growth Rate of M1

January 1960 - December 1998

Figure 17: Growth Rate of M2

January 1960 - December 1998

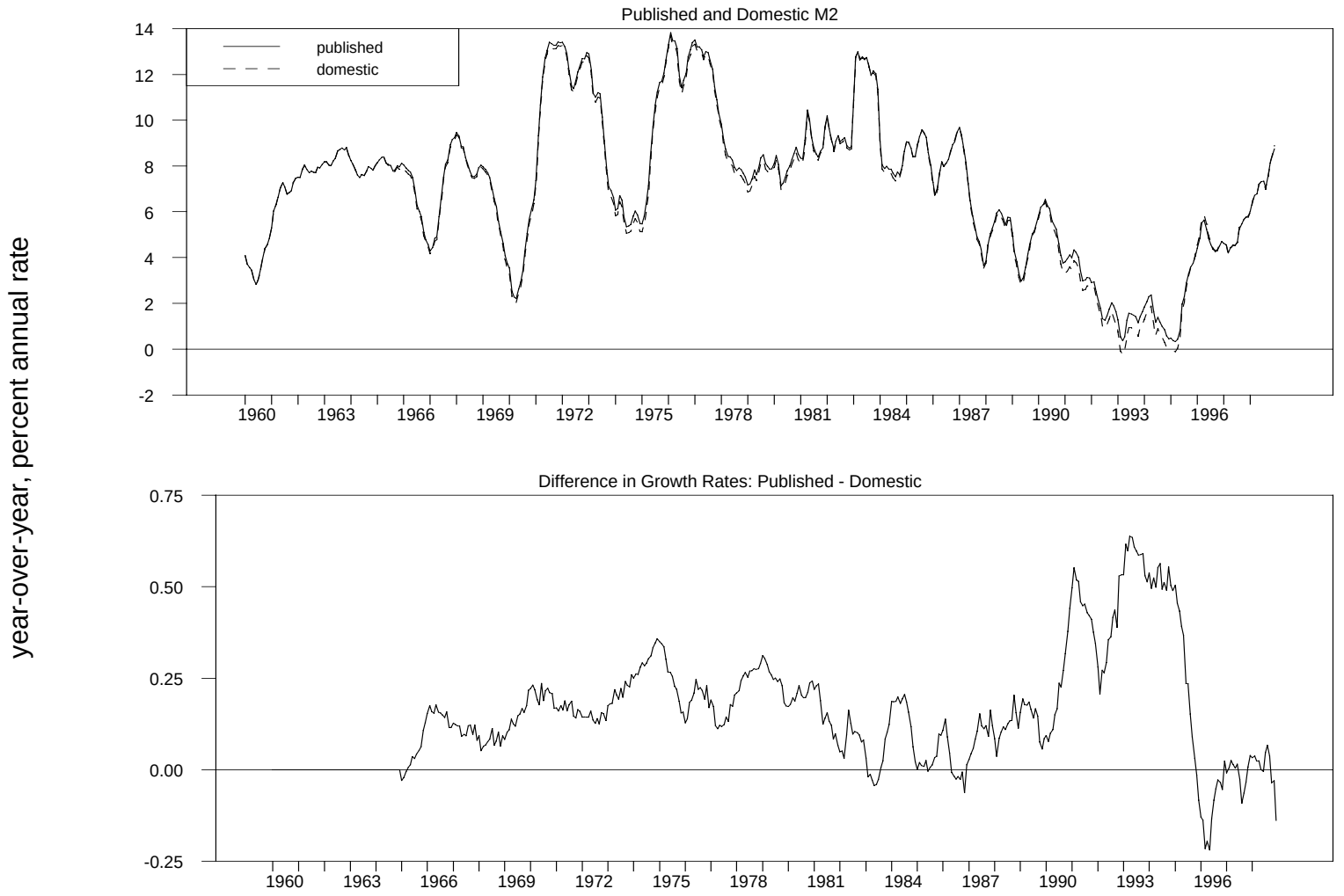


Figure 18: Four Alternative Estimators of the k-ratio

January 1947 - June 1999

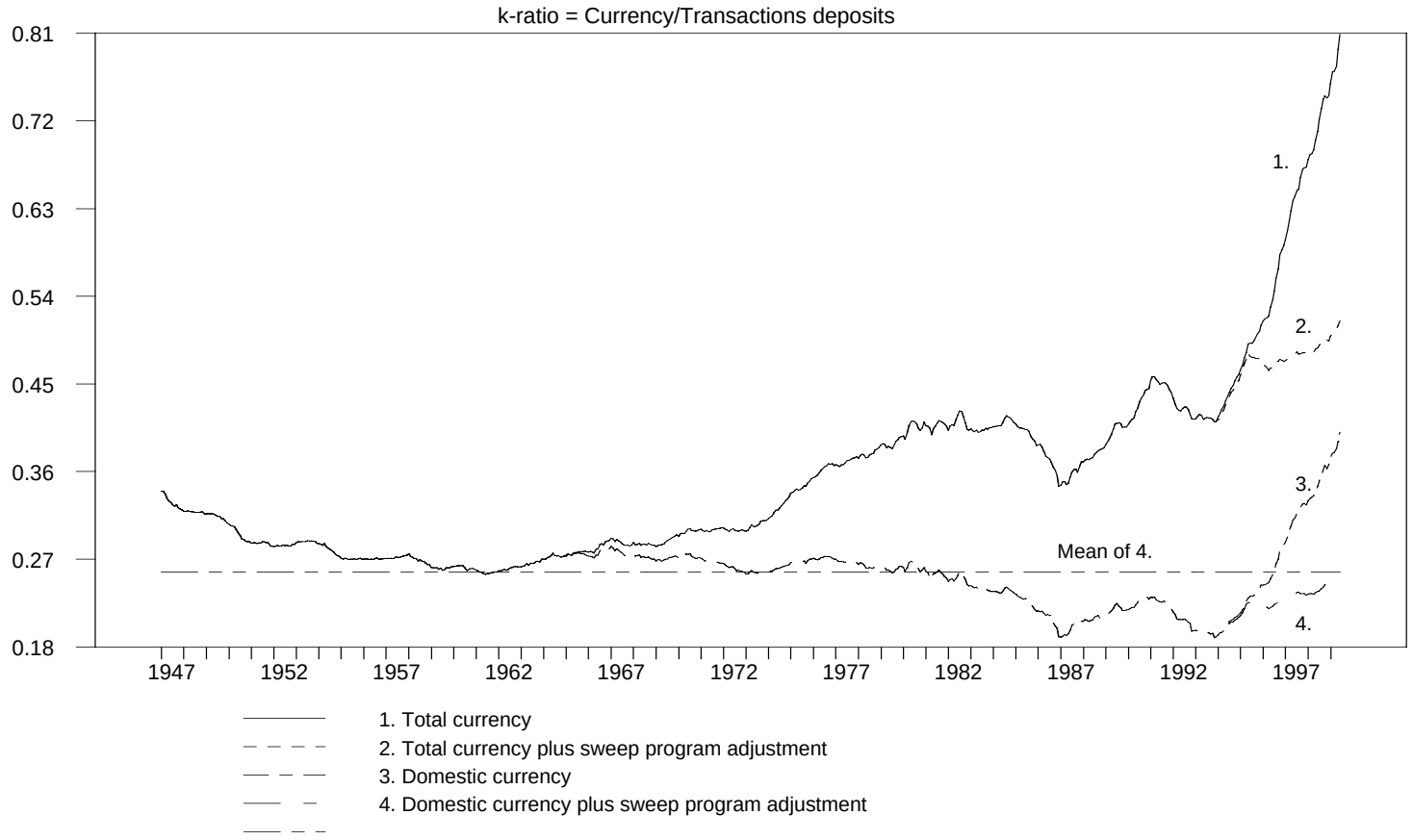


Figure 19: Domestic and Total Velocities

1959 - 1999