BOARD OF GOVERNORS
OF THE
FEDERAL RESERVE SYSTEM
WASHINGTON, D. C. 20551

TO: Federal Open Market Committee DATE: December 28, 1988

FROM: Donald Kohn DK

Attached for your information is a Board staff study of the monetary base, which was sent today to Senator Proxmire in response to a request by the Senate Banking Committee for a study of the role of the base in policy. Most of the material in the study was included in background papers dated February 5, 1988 and May 11, 1988 sent to the FOMC prior to the Committee's consideration of this issue, and was summarized in the appendix to the July Humphrey-Hawkins report. The transmittal letter from Chairman Greenspan to Senator Proxmire also is attached.

Attachments

BOARD OF GOVERNORS
OF THE
FEDERAL RESERVE SYSTEM
WASHINGTON, D. C. 20551

ALAN GREENSPAN
CHAIRMAN

December 28, 1988

The Honorable William Proxmire
Chairman
Committee on Banking, Housing, and
  Urban Affairs
United States Senate
Washington, D.C. 20510

Dear Senator Proxmire:

The report of the Senate Committee on Banking, Housing and Urban Affairs on the Federal Reserve's mid-year monetary policy report requested further study of the advisibility of establishing a range for the monetary base. The enclosed study by Board staff is intended to meet that request. It reveiws the characteristics of the base, the behavior of its velocity, its statistical relationship to income and other variables and its controllability. It compares the base to the other monetary aggregates, and attempts to assess the additional information the base would bring to the policy process. These factors all weighed in the FOMC's consideration of the role of the base in monetary policy. I hope you find the study useful.

In closing let me convey my thanks and those of my colleagues in the Federal Reserve for the many contributions you have made over the years to economic policymaking in the United States. The country has indeed been fortunate to have in a key position a person of your intelligence, integrity, and devotion to the public interest. You have our best wishes for every success in coming endeavors.

Sincerely,

December 1988

THE MONETARY BASE [1]

Summary

In view of the deterioration of the relationship between M1 and GNP and the related decisions by the Federal Reserve in 1987 and 1988 not to set a target range for that narrow aggregate, interest recently has been expressed in the monetary base as a target for, or indicator of, monetary policy. This paper examines the behavior of the monetary base and assesses its potential usefulness for monetary policy.

The first section describes the basic characteristics of the monetary base, with a particular focus on its largest component, currency. The next part describes the performance of the velocity of the base. Next, reduced-form exercises that directly examine the relationship between the monetary base and GNP are presented and compared with analogous relationships for other monetary aggregates. In the fourth section, structural models of demands for components of the base and other aggregates are described. Next, simulations of the Board's structural econometric model of the U.S. economy under targets for the monetary base and other aggregates are presented in terms of likely variability of GNP and prices. Finally, issues related to the controllability of the base are discussed.

The analysis suggests that the monetary base shares some of the behavioral characteristics of M1 that have hindered that aggregate's

1. Study prepared by staff at the Board of Governors of the Federal Reserve System in response to request by Senate Committee on Banking, Housing, and Urban Affairs.

reliability as a monetary target and indicator in the 1980s. The monetary base is dominated by movements in the two principal components of M1: currency and, through reserve requirements, checkable deposits. Reflecting the generally similar movements of M1 and the monetary base, the velocity of the base followed a pattern much like that of M1 during much of this decade, with an unusual net decline over the first six or so years. However, more recently the velocities of M1 and the base have diverged somewhat, owing in part to inexplicably rapid currency growth over the past two years. The potential for anomalous behavior of currency may be heightened by the large proportion apparently held to back activities other than those measured by U.S. GNP, and tends to call into question the benefits of a more significant policy role for the base. Empirical assessment of the targeting and indicator properties of the aggregates indicates that the base does not consistently outperform other monetary aggregates and that the base adds little to the information imparted by the other aggregates, although the predictive performance of all the aggregates for near-term GNP growth in recent years has not been very strong.

Concepts, Definitions, and Measurement[2]

The monetary base consists of currency in the hands of the nonbank public and reserves held by depository institutions--both reserves required to be held against deposits and the additional,

2. This section is drawn from the appendix to the Monetary Policy Report to Congress, Board of Governors of the Federal Reserve System, July 13, 1988.

"excess" reserves that depository institutions choose to hold. Because reserve requirements are substantially higher for transactions deposits (that is, checkable deposits) than for nontransactions deposits, the bulk of required reserves--about three-quarters--is related to transactions deposits.[3] In turn, transactions deposits consist primarily of demand deposits and other checkable deposits, which are important components of the narrow monetary aggregate M1. Thus, both through its currency component and its reserves component, the monetary base is closely related to M1. The links between the monetary base and broader measures of money, such as M2 and M3, are much looser because most savings-type instruments in these measures either are not reservable or have a much lower reserve requirement applied to them. Moreover, currency accounts for a much smaller share of M2 and M3 than of M1.

Looking at the base as the sum of currency and reserves focuses on the monetary liabilities of the Federal Reserve--frequently referred to as the "uses" of the base.[4] Alternatively, the base can be measured from its "sources" in the Federal Reserve balance sheet, that is, the assets held by the System less its nonmonetary liabilities. The two concepts are identical if all components are measured contemporaneously.

There are two publicly available measures of the monetary base. One, corresponding to the uses concept, is constructed by the Board and the other, a sources concept, is produced by the Federal Reserve Bank of

3. The required reserve ratio for nonpersonal time deposits of 18 months or less maturity and for Eurocurrency liabilities is 3 percent; for personal time deposits, it is 0 percent.

4. Technically, the base also encompasses a relatively small amount of U.S. Treasury liabilities in the form of currency.

St. Louis. Besides the difference in accounting approach, which in practice creates a gap between the two because of lags in the treatment of vault cash, the two measures differ in the method of adjustment for changes in reserve requirements and in the method of seasonal adjustment.

The Board measure constructs the base from the currency component of the money stock (currency held by the nonbank public) (76 percent), total reserves (lagged vault cash, up to the institution's required reserves, plus reserve deposits at the Federal Reserve Banks) (23 percent), and a third component that includes current surplus vault cash held at depository institutions plus service-related balances at Reserve Banks (1 percent)[5].

The St. Louis measure, consistent with its sources concept, comprises Federal Reserve credit--holdings of U.S. government securities, discounts and advances, Federal Reserve float, and other Federal Reserve assets--plus other sources, including the gold stock, Special Drawing Rights, and Treasury currency outstanding. It subtracts several categories of liabilities, namely, Treasury and foreign deposits at the Federal Reserve, Treasury holdings of coin and currency, and certain miscellaneous items. Implicitly, all vault cash is treated contemporaneously.

5. _Vault cash_ included in total reserves is lagged four weeks, reflecting its use to meet reserve requirements. _Surplus vault cash_ is holdings of currency by depository institutions in excess of required reserves. _Service-related balances_ comprise other balances held by depository institutions at the Federal Reserve, including required clearing balances and adjustments to compensate for Federal Reserve float.

Chart 1 portrays the St. Louis and Board measures of the monetary base. The upper panel shows that the two measures have moved together over time, though the St. Louis measure generally lies above the Board measure, reflecting differences in techniques for adjustment of breaks caused by changes in reserve requirements.[6] The lower panel shows that, in terms of growth rates, the two series track each other closely. Henceforth, this paper will analyze the Board's measure.

Behavior of Currency. Over most of the period since 1960, growth of currency has been fairly well-behaved--that is, largely explainable in terms of its historical relationship with other variables. Board staff models of the demand for the currency component of the money stock, which relate the quantity of currency to measures of spending and interest rates, as well as to a trend, explain nearly 100 percent of the variance in currency growth within the sample period used for estimation, as discussed in more detail below. (See Table 1; definitions of variables used in the money demand equations are presented in the appendix.)

Chart 2 portrays the relationship between four-quarter growth rates of currency and personal consumption expenditures, the most important variable explaining currency movements in the Board staff model.

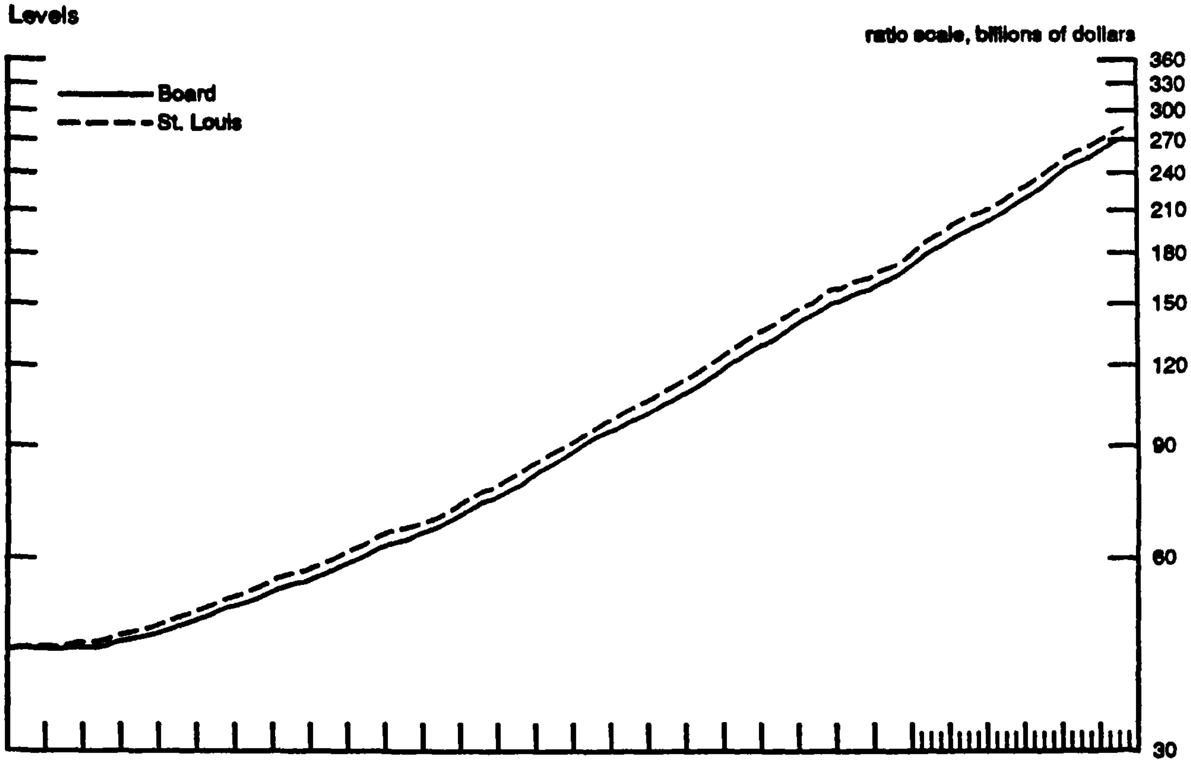
6. The St. Louis base is seasonally adjusted directly after the addition of a reserve adjustment magnitude (RAM) to account both for regulatory changes in reserve requirements and for changes in the composition of deposits. For the Board measure, currency, total reserves, and the residual component are seasonally adjusted separately, after applying to the reserves and residual components certain "break adjustment" factors, and finally the components are summed. The Board's break-adjustment method adjusts only for regulatory changes in reserve requirements, and not for changes in the composition of deposits.

Chart 1

December 6, 1988

Measures of the Monetary Base

Levels



Growth Rates

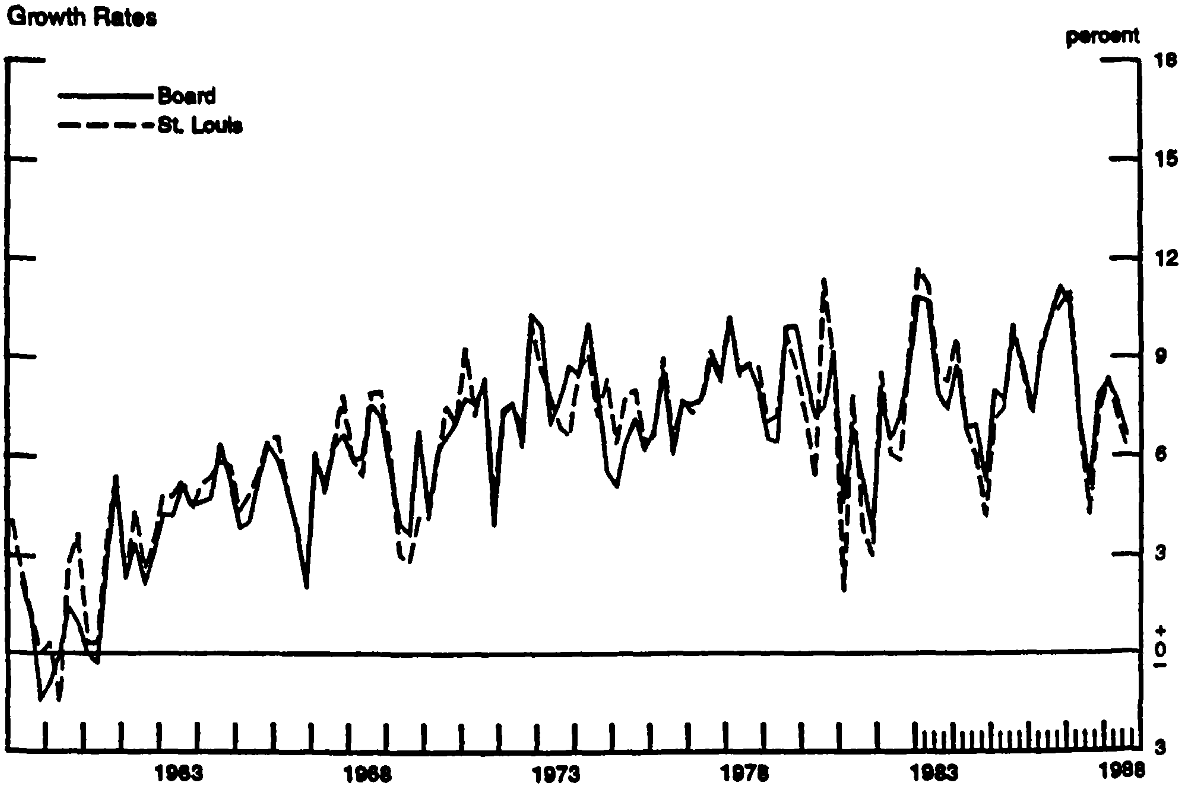


Table 1
Board Staff Econometric Model[1]
Demand for the Currency Component of the Money Stock

$$\log(\text{CURR}) = \underset{[-4.4]}{-1.5188} + \sum_{i=0}^{4} r_i \, \text{RTBE}_{-i} + \sum_{i=0}^{5} yc_i \log(\text{EPCE})$$

$$+ \sum_{i=0} p_i \log(\text{PEPCE})_{-i} - \underset{[-3.2]}{.0015}\,\text{TYME} + \underset{[15.3]}{1.3215}\,U_{-1} - \underset{[-5.9]}{.4989}\,U_{-2}$$

$\Sigma r_i = -.0054$ [-6.8]	$\Sigma yc_i = .8838$ [16.5]	$\Sigma p_i = 1$ [constrained]
$r_0 = -.0003$	$yc_0 = .0935$	$p_0 = .1630$
$r_1 = -.0018$	$yc_1 = .1399$	$p_1 = .1560$
$r_2 = -.0017$	$yc_2 = .2908$	$p_2 = .4284$
$r_3 = -.0008$	$yc_3 = .1297$	$p_3 = .2526$
$r_4 = -.0008$	$yc_4 = .1113$	
	$yc_5 = .1187$	

$\bar{R}^2 = .99998$
Durbin-Watson Statistic = 2.1553
Standard Error of Regression = .0026
Sample Period: 1961:Q1 - 1986:Q2.
Estimated: 8/87

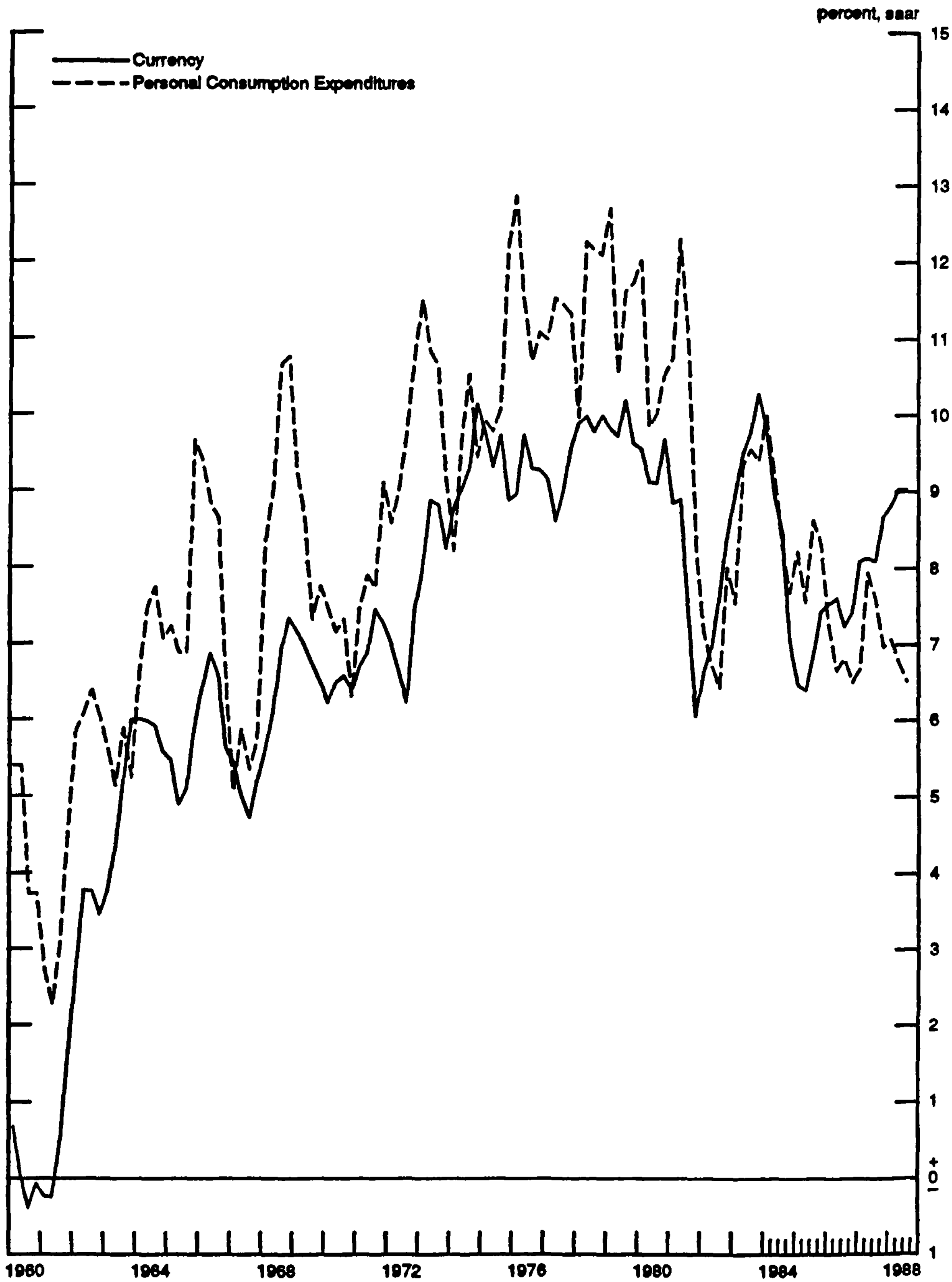
t-statistics in brackets.
1. See appendix for variable definitions.

Chart 2

December 6, 1988

CURRENCY AND PERSONAL CONSUMPTION EXPENDITURES

Four-quarter growth rates



There is a generally close relationship between these series, with currency growth tending to rise and fall with growth of consumption spending; though there have been deviations from time to time, generally these deviations have been rather short term. However, growth of currency has run substantially above that of personal consumption expenditures in the last few years--an unprecedented development--for no readily apparent reason.

Deviations of currency from expected levels based on measured economic activity in the United States may reflect its apparent usage for other purposes. The amount of currency in the hands of the public divided by the resident population of the United States indicates that on average more than $800 is outstanding per person. While this calculation does not make allowance for currency held by businesses, it clearly suggests that a significant share of the total stock of currency is not, in fact, circulating or held in the United States in support of ordinary domestic economic activity.[7] The Federal Reserve's Survey of Currency and Transactions Account Usage also supports such a conclusion, with the survey responses indicating that only about one-eighth of outstanding currency can be accounted for by domestic households.[8] Unfortunately, we have essentially no information on how much currency is held outside this country for spending or as a store of value.

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7. The Federal Reserve's and the Small Business Administration's Survey of Small Business Finances, results of which likely will be available in autumn 1989, should be able to shed more light on the amount of currency held by businesses.
8. See 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, Volume 72, February 1986, pp. 87-108.

An analysis of currency by denomination also suggests that a large volume of dollar currency is either supporting illegal activities or is being used as a store of value in the U.S. or elsewhere. Chart 3 shows the composition of currency by denomination.[9] Although small denomination bills--up to, say, $50--clearly are a substantial part of overall currency, nearly 50 percent in 1988 is made up of $100 bills and, to a much lesser extent, larger denominations. The amount of $100 and larger bills has increased rapidly since 1970, at an average 13.4 percent annual rate. While some increase would be expected owing to the larger average size of purchases as prices and incomes have increased, the rate of rise seems larger than can be explained by these factors. These denominations are the ones most likely to be used in support of illegal activities or as a store of wealth. Moreover, large denomination bills have a seasonal pattern of substantially smaller amplitude than that for other bills, tending to support the hypothesis that these bills are used differently than other currency.

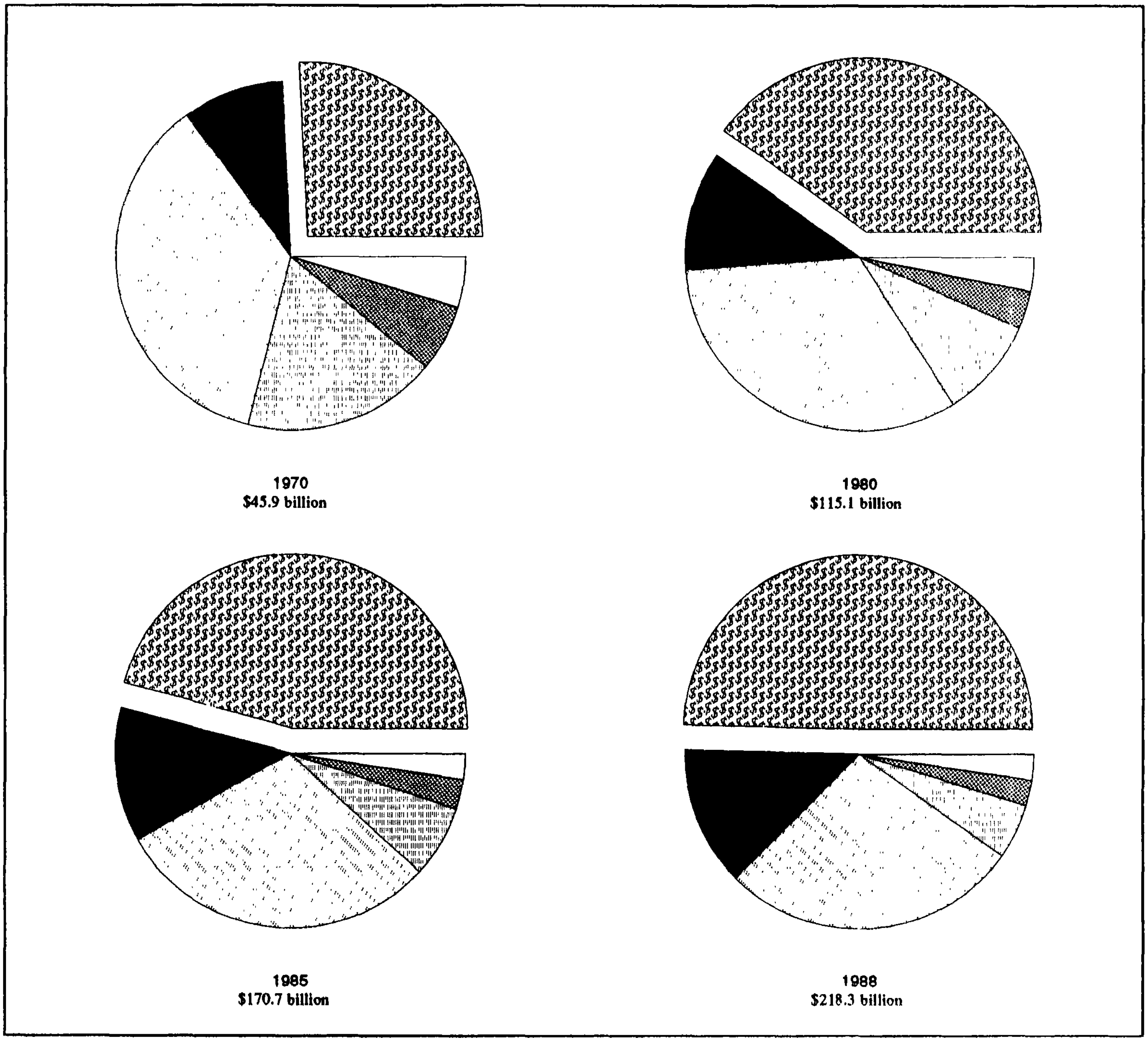
Thus, the recent pattern of currency growth, along with an examination of its denominations, tends to cast doubt on the strength of the association between currency and aggregate U.S. spending. Unless the activities that rely on large-denomination currency, as well as other offshore uses of U.S. currency, were closely correlated over time with U.S. GNP, they would tend to impair any association between the monetary base and GNP.

9. Unlike the figures for currency in the hands of the nonbank public that were discussed above, figures on currency by denomination include holdings by depository institutions.

Chart 3

Composition of Currency by Denominations

(based on dollar amount outstanding)



– one– and two–dollar bills

– five–dollar bills

– ten–dollar bills

– twenty–dollar bills

– fifty–dollar bills

– one–hundred–dollar and larger bills

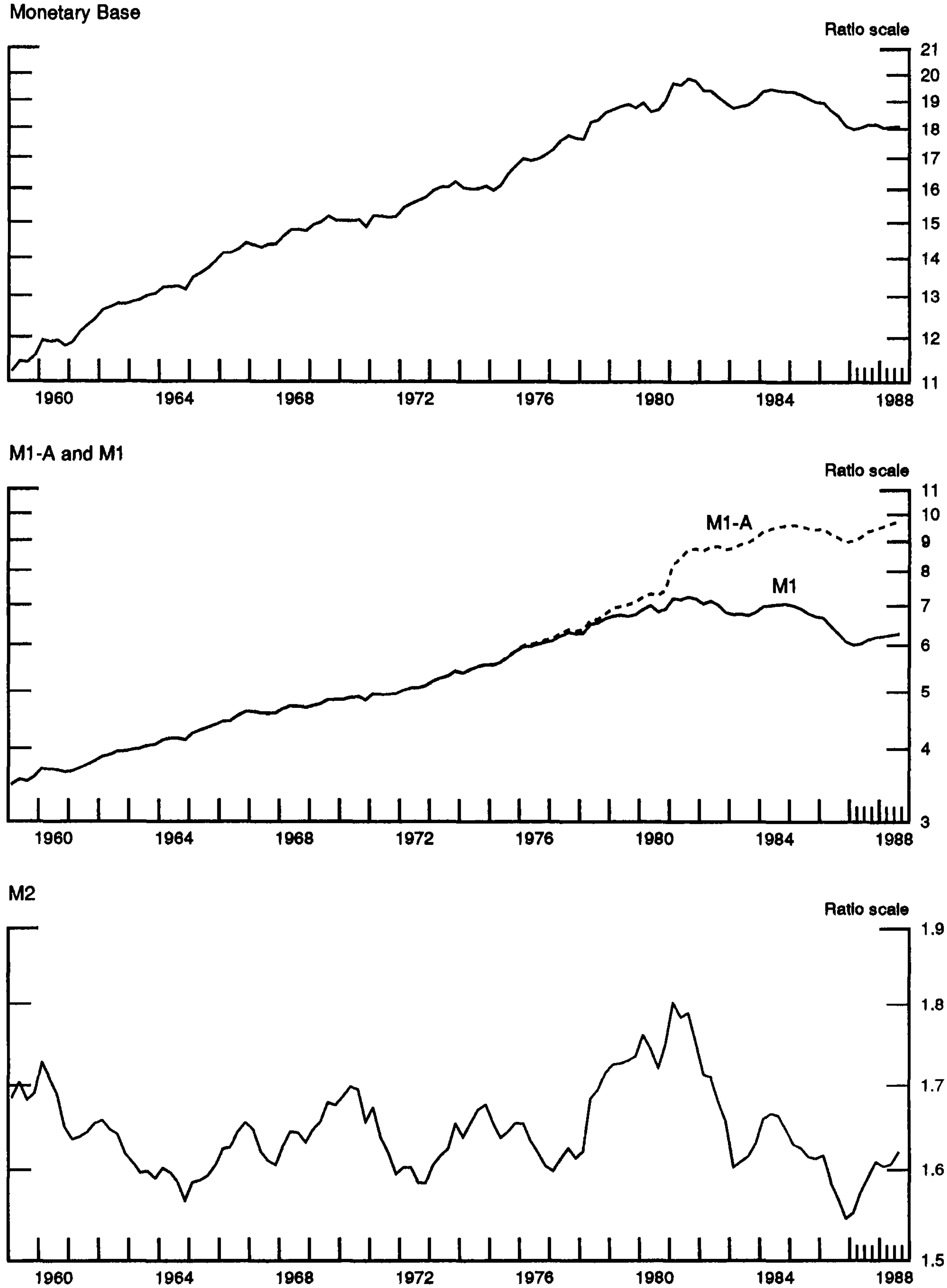
Velocity of the Monetary Base

Chart 4 portrays the velocity of the base (that is, nominal GNP divided by the monetary base) along with velocities of other monetary aggregates. Base velocity has behaved in a manner broadly similar to that of M1, generally rising over the 1960s and 1970s before declining on net in the 1980s. (To be sure, M1 velocity has varied more in percentage terms than has base velocity in the 1980s.) To an extent, the weakness in base velocity over much of this decade reflects the rapid increase in required reserves associated with growth of NOW accounts following their authorization on a nationwide basis in early 1981; these accounts apparently attracted large volumes of savings funds, as well those held in transaction accounts. Flows into NOW accounts were especially strong for several years because the net decline in nominal interest rates since the early 1980s tended to reduce the opportunity cost of holding funds in these accounts. Finally, base velocity has levelled off in the last few years, rather than rising along with M1 velocity, reflecting the rapid growth of currency relative to income.

Thus, the monetary base could be viewed as sharing velocity characteristics with M1, though muted quantitatively. This is not surprising, since the base can be viewed as essentially a weighted average of the components of M1, with currency receiving a relatively large weight and the transactions deposit component, through reserve requirement ratios, receiving a smaller weight.

Chart 4

Velocities of the Monetary Aggregates



Reduced-Form Relationships Between GNP and Monetary Aggregates

A common method of assessing the relationship between changes in a monetary aggregate and subsequent movements in GNP or inflation is to use reduced-form equations. Reduced forms directly relate the two variables of interest through econometric regression techniques. These equations are called "reduced forms" because they ignore the relevant economic structure and attempt to short-circuit the economic chain of causation by considering only the initial cause and the final effect.[10]

The following tables and charts summarize a set of reduced-form equations that relate growth in nominal GNP to various measures of money and a measure of fiscal stimulus.[11] The money stock variables include the monetary base, M1-A, M1, and M2. The equations were estimated using ordinary least squares over the period from 1961:Q2 through 1979:Q4 and simulated for the period from 1980:Q1 through 1988:Q3. In order to take account of the possibility that the predictions might be distorted by unusual shifts of deposit balances during periods when new deposit instruments--NOW accounts and MMDAs--were being introduced in the early 1980s, simulations are reported both for unadjusted versions of M1-A,

10. Reduced-form equations have a number of econometric problems. One of the most potentially significant arises from the fact that they abstract from the simultaneous determination of a number of economic variables such as GNP and the quantity of money.
11. The measure of fiscal stimulus chosen is the quarterly percentage change in the high-employment budget deficit scaled by potential GNP at an annual rate. The high-employment deficit and potential GNP are based on a concept of mid-expansion trend GNP. As data for these two concepts for 1988:Q3 have not yet been published by the Bureau of Economic Analysis, Board staff estimates for that quarter were used.

M1, and M2 and for versions that have been adjusted for such shifts.[12]

The expressions allow for a lagged response of GNP to money growth and fiscal stimulus, with responses spread over as many as eight quarters. The coefficients on the monetary variables are constrained to sum to one, consistent with monetary neutrality over a substantial period of time.[13]

Estimation results are presented in Table 2. As is typically the case with such reduced-form equations, only a small proportion of the variance of GNP growth is explained, ranging from around 27 percent to about 40 percent, with the base turning in the poorest performance of the aggregates. When the number of explanatory variables is taken into account, the proportion of variance explained (as measured by the adjusted R-squared) drops to a range of 6 percent to 21 percent. Again, the base performs worst.

The ability of econometric equations to forecast outside of the sample period over which they were estimated is another way to judge the usefulness of their explanatory variables. Summary measures of the forecasting performance of the various aggregates can be found in Chart 5 and Table 3. In general, the predictive power of the monetary base is no better than average among the measures considered. Over the 1980s to date, the monetary base had a mean absolute error of 4.8 percentage points in forecasting quarterly GNP growth rates, compared with a range

12. Estimation results are reported only for not-shift-adjusted versions, because over the estimation sample period, growth rates of the not-shift-adjusted variables are the same those for their shift-adjusted counterparts, since most deposit deregulation occurred after 1979:Q4.
13. Although the sum of the monetary coefficients were constrained to unity, the distributed lags were not constrained in any other way.

Table 2

Reduced-Form Equations
Dependent Variable: Growth of Nominal GNP
(percent change, annual rate)

	Base	M1-A	M1	M2
Intercept	2.2	3.4	3.2	.3
Monetary Sum[1]	1.0	1.0	1.0	1.0
Fiscal Sum	6.0	3.6	3.5	1.8
$\bar{R}^2$	.06	.19	.21	.18
Residual Standard Error	3.7	3.4	3.4	3.5

Estimation period: 1961:Q2 - 1979:Q4.
Nominal GNP and monetary variables measured as quarterly percent changes at annual rates; fiscal variable is quarterly change in the high employment budget surplus (expressed at an annual rate) as a percentage of nominal potential GNP.
1. Constrained to unity.

Chart 5

Nominal GNP Growth Errors From Reduced Form Equations

Actual minus Predicted

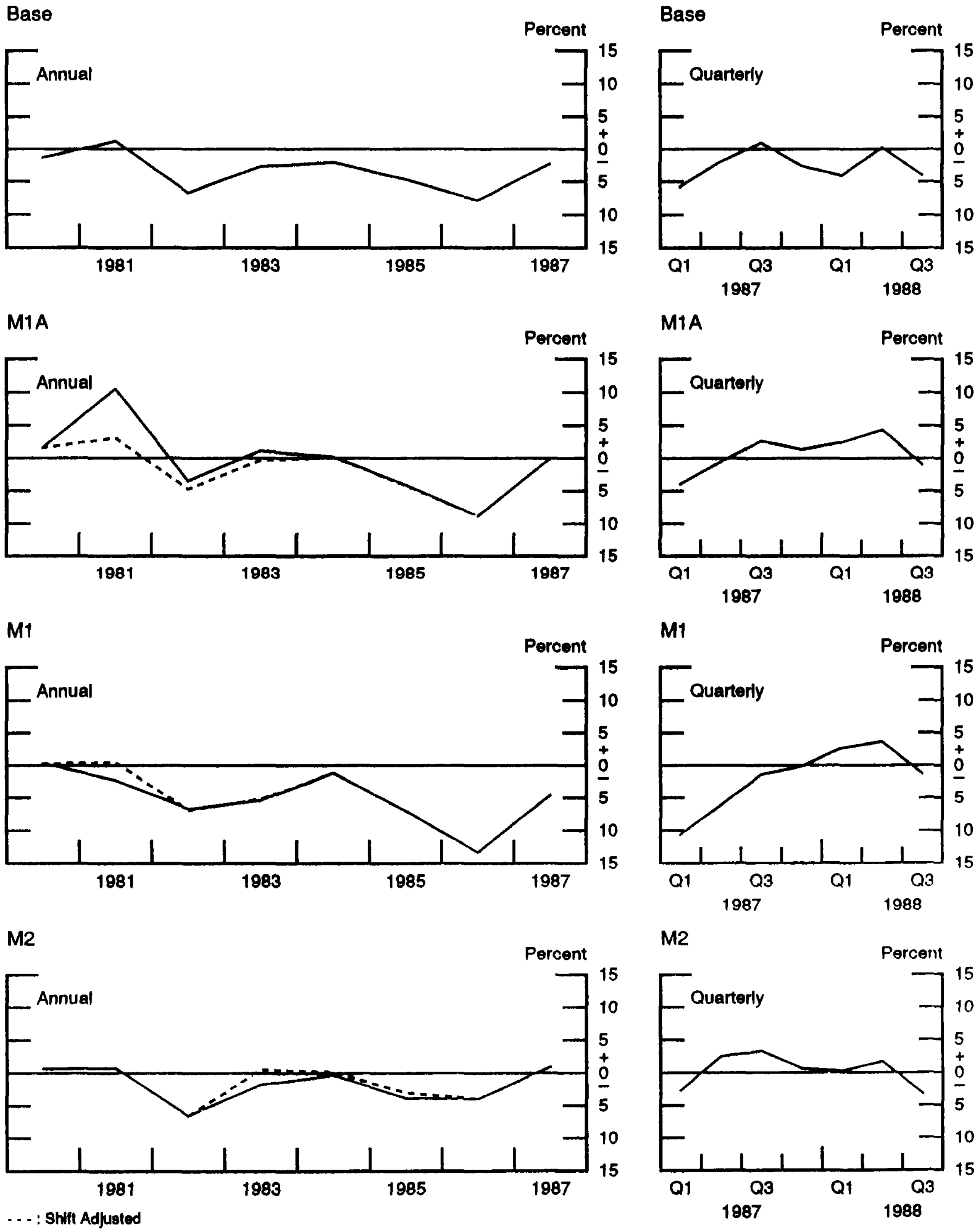


Table 3

Simulations of Reduced-Form Equations
Dependent Variable: Growth of Nominal GNP
Error Statistics
(percentage points)

	Base	M1-A	M1-ASH	M1	M1SH	M2	M2SH
Mean absolute error	4.8	5.1	4.5	6.1	6.1	4.3	3.9
Root mean square error	5.6	6.7	5.7	7.4	7.5	5.5	5.1
Bias (mean error)	-3.3	-.2	-1.4	-4.5	-4.1	-1.6	-1.2

Simulation period: 1980:Q1 - 1988:Q3
SH: shift-adjusted

of 3.9 percentage points (for shift-adjusted M2) to 6.1 percentage points (for both versions of M1). Like all the other aggregates, the base also was a biased predictor of GNP growth, over-forecasting by 3.3 percentage points on average. This bias compares with 1.2 percentage points for M2 shift-adjusted (smallest bias) and 4.5 percentage points for M1 not-shift-adjusted (largest bias). The particularly large biases and mean absolute errors of M1 highlight the pronounced effect that deregulation had on the relationship of that aggregate to economic activity.

The equations described above examine the monetary variables in isolation from one another. However, the monetary base may add to information conveyed by other monetary variables. In order to test this hypothesis, additional reduced-form equations were estimated. These equations augment the reduced-form equations for the each of the other monetary aggregates by including current and lagged values of the base. The sum of the coefficients on the base and the other monetary variables was constrained to one, for the reason mentioned previously. By examining the joint statistical significance of the coefficients for the base, the marginal information value of the base can be assessed. As shown by the F-statistic in Table 4, the equations indicated that the base was adding essentially no information within the sample period to that conveyed by the other monetary variables.

The marginal predictive contribution of the base was tested by simulating the previous equations over the 1980s. As can be seen by comparing Table 5 with Table 3, addition of the monetary base uniformly

Table 4

Reduced-Form Equations
Dependent Variable: Growth of Nominal GNP
Addition of Monetary Base Variable

	M1A	M1	M2
Intercept	3.2	3.1	.9
Monetary sum[1]	1	1	1
F-statistic: monetary base coefficients	.36	.33	.16
Fiscal sum	3.2	3.9	2.7
$\bar{R}^2$	.14	.16	.07
Residual standard error	3.6	3.5	3.6

1. Sum of monetary base and other monetary aggregate coefficients constrained to unity.

Table 5

Simulations of Reduced-Form Equations
with Addition of Monetary Base
Dependent Variable: *Growth of Nominal GNP*

Error Statistics
(percentage points)

	M1-A	M1-ASH	M1	MISH	M2	M2SH
Mean absolute error	5.5	4.9	6.4	6.2	4.9	4.4
Root mean square error	7.3	6.1	7.9	7.9	6.1	5.6
Bias (mean error)	-1.0	-1.9	-4.4	-4.1	-2.1	-1.9

Simulation period: 1980:Q1 - 1988:Q3
SH: shift adjusted

worsened the other aggregates' predictive performance as measured by mean absolute errors and bias. (The errors are portrayed in Chart 6.) Thus, both in-sample and out-of-sample reduced-form experiments suggest that the monetary base has little predictive power for GNP and does not augment the predictive abilities of the other aggregates.

Structural Models of Demand for the Base

Although the previous reduced-form exercises may provide some information on the relationship between movements in the monetary aggregates and nominal GNP, econometric problems tend to limit the confidence one can place in these results. In addition, the reduced form approach does not permit structural analysis of the relationship between money or base aggregates and GNP.

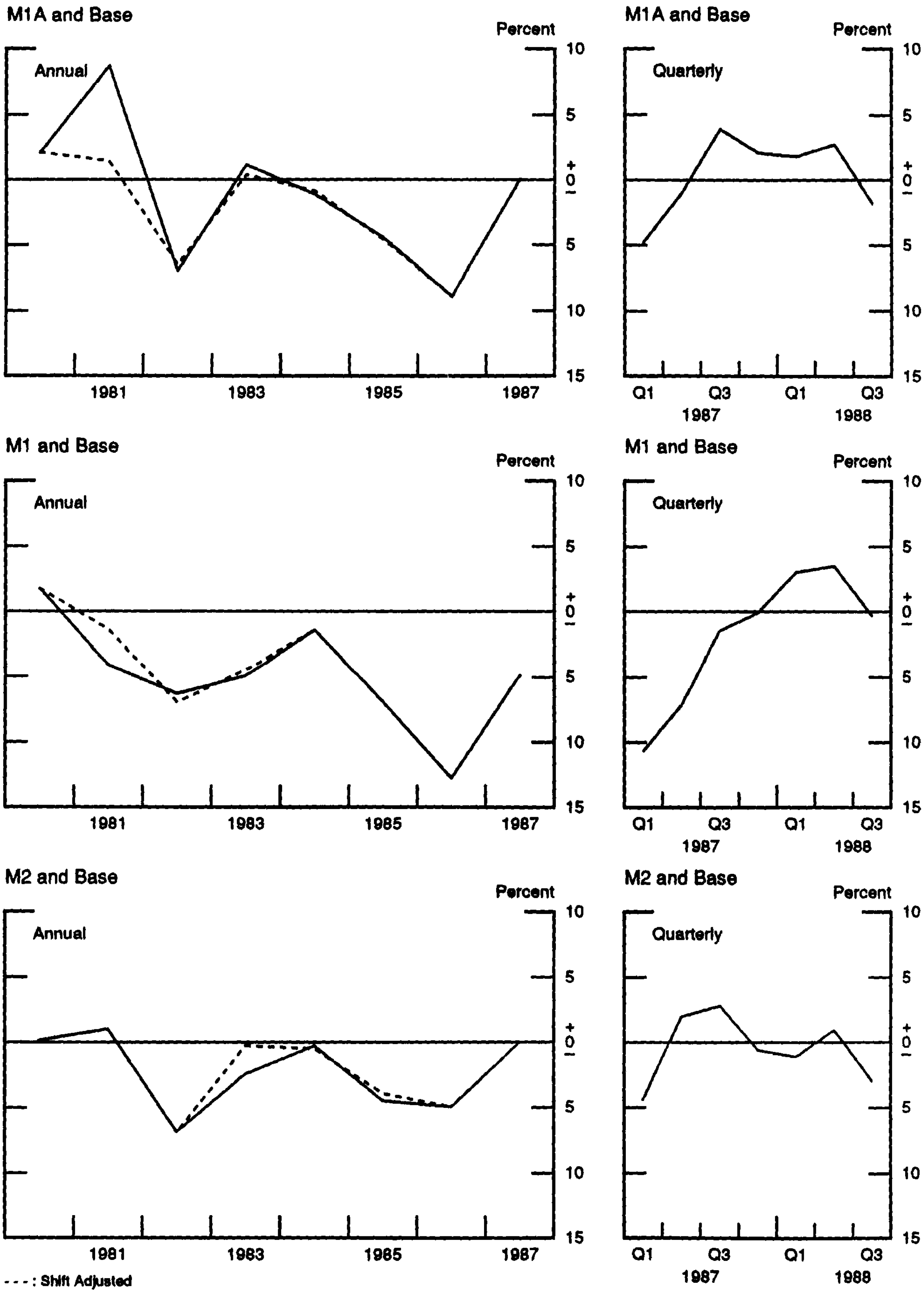
An alternative approach to understanding the economic significance of the monetary base is to make use of existing structural models of demands for components of the base. In this section, these models of the demands for currency in circulation and reserve balances are analyzed.[14] The following section presents results of simulation experiments involving these structural models as well as the staff quarterly macroeconomic (MPS) model; these simulation experiments are designed to analyze the ability of alternative monetary targets to stabilize GNP and prices.

14. Ignoring the lag in vault cash in total reserves, this decomposition of the base on the uses side is equivalent to the sum of total reserves, the currency component of the money stock, and surplus vault cash.

Chart 6

Nominal GNP Growth Errors From Reduced Form Equations

Actual minus Predicted



Currency demand. The willingness of the public to hold currency generally is thought to be responsive primarily to two variables: the level of spending by the public and the opportunity cost of holding currency. The staff's model of demand for the currency component of the money stock was summarized in Table 1. The model was estimated by ordinary least squares over the period from 1961:Q1 to 1986:Q2. As noted above, the model fits the data quite well over the sample period, explaining nearly 100 percent of the variance in quarterly percentage changes in currency demand.

The simulation approach discussed below uses an equation for currency in circulation, rather than the currency component of the money stock. Therefore, an equation for currency in circulation was estimated using the same functional form and sample period as that for the currency component. (See Table 6.) The two equations fit the sample data about equally well and have similar coefficients.

Demand for Reserve Balances. Most of the variance in required reserves derives from changes in required reserves against transactions deposits, rather than against other reservable liabilities--nonpersonal time and savings deposits and Eurocurrency liabilities. Moreover, all of the error in predicting required reserves within a reserves maintenance period--a relevant consideration when analyzing the targeting performance of the base--is due to reserves against transactions deposits, owing to the lagging of reserve requirements against other liabilities. In addition, most variance in required reserves against transactions deposits reflects changes in transactions deposits included

Table 6
Board Staff Econometric Model[1]
Demand for Currency in Circulation

$$\log(CIC) = \underset{[-4.3]}{-1.79} + \sum_{i=0}^{4} r_i \, RTBE_{-i} + \sum_{i=0}^{5} yc_i \log(EPCE)$$

$$+ \sum_{i=0}^{3} p_i \log(PEPCE)_{-i} - \underset{[-4.3]}{.0023} \, TYME + \underset{[15.5]}{1.263} \, U_{-1} - \underset{[-5.1]}{.384} \, U_{-2}$$

$\Sigma r_i = -.0041$ [-5.2]	$\Sigma yc_i = .945$ [14.6]	$\Sigma p_i = 1$ [constrained]
$r_0 = -.0001$	$yc_0 = .1139$	$p_0 = .1950$
$r_1 = -.0016$	$yc_1 = .1959$	$p_1 = .1696$
$r_2 = -.0013$	$yc_2 = .2711$	$p_2 = .4092$
$r_3 = -.0003$	$yc_3 = .1099$	$p_3 = .2262$
$r_4 = -.0007$	$yc_4 = .0958$	
	$yc_5 = .1159$	

$\bar{R}^2 = .99998$
Durbin-Watson Statistic = 2.1189
Standard Error of Regression = .0026
Sample Period: 1961:Q1 - 1986:Q2.
Estimated: 1/88

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t-statistics in brackets.
1. See appendix for variable definitions.

in M1--demand deposits and other fully checkable deposits due to individuals, partnerships, and corporations. Thus, changes in the demand for reserve balances are specified as 8-1/2 percent of changes in the demand for transactions balances--demand deposits plus other checkable deposits in M1.[15,16]

The estimated demand equations for demand deposits and for other checkable deposits are shown in Tables 7 and 8. These equations specify demand for each of these monetary components primarily as a function of its opportunity cost--measured as the difference between the interest rate on Treasury bills and the own rate on the monetary asset--and of personal consumption expenditures. In addition, the equation for demand deposits includes a time trend and variables to account for the shifting of funds associated with the authorization of NOW accounts.[17,18] The deposit equations are not as accurate within the sample as the currency equations, explaining around three-fourths of the variance in growth rates.

15. The average marginal reserve ratio against transactions deposits is estimated to be about 8-1/2 percent. The average marginal reserve ratio is less than 12 percent because of the reserve requirement exemption on the first $3.4 million of reservable liabilities and the 3 percent low reserve tranche on the first $41.5 million of net transaction accounts. (These amounts are effective December 20, 1988.)

16. The other component of reserves, vault cash applied to satisfy reserve requirements, as well as surplus vault cash, are included in currency in circulation.

17. The other checkable deposits equation is estimated beginning in 1981:Q3, after much of the shift into NOW accounts had been completed, and therefore does not include variables for the shift.

18. The equations incorporate a so-called error correction specification, whereby the quantity demanded is assumed to have a long-run relationship with certain variables and deviations from these long-term relationships are "corrected" or eliminated in a specified manner over time.

Table 7
Board Staff Econometric Model[1]
Demand for Demand Deposits

$$\Delta\log(DD) = \underset{[-2.5]}{-.1222} - \underset{[-3.2]}{.0183} \log(RTBE)_{-1}$$

$$- \underset{[-2.5]}{.1749} [\log(DD) - \log(EPCEN)]_{-1}$$

$$- \underset{[-2.2]}{.0010} \, TYME_{-1} - \underset{[-2.7]}{.0030} \, SHIFT_{-1}$$

$$+ \underset{[2.2]}{.1649} \log(1 - JNOWT)_{-1} + \sum_{i=0}^{1} dr_i \, \Delta\log(RTBE)_{-i}$$

$$+ \sum_{i=0} dy_i \, \Delta\log(EPCEN)_{-i} - \underset{[-3.3]}{.0089} \, \Delta SHIFT$$

$$+ \underset{[11.3]}{.8834} \, \Delta\log(1 - JNOWT) + \underset{[2.5]}{.1535} \, \Delta\log(DD)_{-1}$$

$$\sum dr_i = \underset{[-3.4]}{-.0305} \qquad \sum dy_i = \underset{[13.6]}{.8465}$$

$$dr_0 = -\ .0081 \qquad dy_0 = .4868$$

$$dr_1 = -.0224 \qquad dy_2 = .1661$$

One convergence restriction is imposed on the estimates:

$$\sum_{i=0} dy_i + \text{coefficient on } \Delta\log(DD)_{-1} = 1$$

$\bar{R}^2$ = .7671
Durbin H Statistic = -.6331
Standard Error of Regression = .0068
Sample Period: 1961:Q1-1986:Q2
Estimated: 8/87

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t-statistics in brackets.
1. See appendix for variable definitions.

Table 8
Board Staff Econometric Model[1]
Demand for Other Checkable Deposits

$$\Delta\log(OCD) = \underset{[-4.1]}{-.5083} - \underset{[-4.0]}{.0514}\ TAYLOG1_{-1}$$

$$- \underset{[-4.2]}{.2047}\ [\log(OCD) - \log(EPCEN)]_{-1}$$

$$- \underset{[-2.3]}{.0250}\ \Delta TAYLOG1 + \underset{[7.9]}{.8580}\ \Delta\log(EPCEN)$$

$$+ \underset{[1.3]}{.1420}\ \Delta\log(OCD)_{-1}$$

One convergence restriction is imposed on the estimates:
sum of coefficients on $\Delta\log(EPCEN)_{-1}$ and $\Delta\log(OCD)_{-1} = 1$

$\bar{R}^2 = .7835$
Durbin H Statistic = -.9373
Standard Error of Regression = .0293
Sample Period: 1981:Q3-1986:Q3
Estimated: 8/87

t-statistics in brackets.
1. See appendix for variable definitions.

For purposes of comparison, results from an M2 model maintained by the Board staff also are presented below. This equation (summarized in Table 9) models M2 as a whole, using as explanatory variables GNP and wealth as well as the weighted average opportunity cost of components of M2. The equation has somewhat larger percentage errors within the sample period than do the equations for currency in circulation, the currency component, and other checkable deposits, and smaller percentage errors than the equation for demand deposits.

Over the period 1964:Q2 to 1986:Q2, which roughly encompasses the sample periods used for estimation, the equations explain comparable percentages of variance in growth of the aggregates. For the base, M1-A, M1, and M2, the unadjusted R-squared values are .72, .76, .69, and .63, respectively.

Table 10 presents forecast error statistics for the currency in circulation, demand deposit, and other checkable deposit demand equations (lower panel) as well as for the base, M1-A, M1, and M2 (upper panel). The statistics for M1-A and M1 are derived by summing predictions of equations for their components. The demand deposit equation experienced large prediction errors in recent years, underpredicting by 5 percentage points in 1986 and overpredicting by 6-1/2 percentage points in 1987 and 5-1/2 percentage points in 1988. (Error statistics for 1988 are for the first three quarters of the year.) Errors in the other checkable deposits equation were fairly small over 1986 and 1987,

Table 9
Board Staff Econometric Model
Quarterly Aggregate M2 Equation

$$\Delta\log(M2) = \underset{(-4.88)}{-.0728} - \underset{(-2.52)}{.0012}\ TIME + \underset{(2.35)}{.0062}\ MMDADUM$$

$$\underset{(-6.62)}{-.0119}\ TAYLOG_{-1}$$

$$\underset{(-5.18)}{-.1899}\ [\log(M2) - \log(GNP]$$

$$\underset{(1.22)}{+.0776}\ \Delta\log(GNP)$$

$$\underset{(-5.06)}{-.0090}\ \Delta TAYLOG$$

$$+\sum_{i=0}^{2} w_i\ \Delta\log(WEALTH)_{-i}$$

$$-\ \underset{(-4.034)}{.0156}\ \Delta DUMMCON$$

$$+\ \underset{(4.97)}{.0314}\ \Delta\ MMDADUM$$

$$+\ \underset{(6.47)}{.493}\ \Delta Log\ (M2)_{-1}$$

$\Sigma_i w_i = \underset{(5.64)}{.4292}$, $w = \underset{(1.90)}{.123}$ $\qquad w_i = \underset{(1.13)}{.076}$ $\qquad w_2 = \underset{(3.64)}{.231}$

Restrictions: $\Sigma y_i + \Sigma w_i + dm = 1$

where dm = .429--the coefficient on lagged $\Delta\log(M2)$.

Sample Period: 1968:1 - 1986:2
$\bar{R}$-squared: .669
Durbin-H statistic: .126
Standard Error of the Regression: .00478

Table 10

MONEY DEMAND GROWTH RATE FORECAST ERRORS[1]
(percent)

	Base[2]	M1-A[3]	M1[4]	M2[5]
Summary Statistics for Quarterly Errors 1985:Q1 - 1988:Q3				
Root Mean Squared Error	1.7	3.3	2.7	2.1
Mean Absolute Error	1.6	2.4	1.9	1.9
Mean Error	.6	-.5	.1	-.5
Annual Errors				
1985	-.8	-.1	.2	-1.1
1986	1.4	3.3	1.8	1.2
1987	.1	-3.5	-2.5	-1.9
1988[6]	2.3	-1.9	1.3	.1

	CIC	DD	OCD
Summary Statistics for Quarterly Errors 1985:Q1 - 1988:Q3			
Root Mean Squared Error	1.9	5.7	5.0
Mean Absolute Error	1.3	4.5	3.8
Mean Error	1.2	-1.7	1.2
Annual Errors			
1985	-.1	-.4	1.0
1986	.8	4.8	-2.0
1987	1.8	-6.7	-.3
1988[6]	2.8	-5.4	7.3

1. Based on long-run simulations starting in 1984:Q4.
2. Based on currency in circulation, demand deposit, and other checkable deposit equations, and an assumed marginal reserve ratio of .085 on transactions deposits. Excludes multiplier errors.
3. Based on the currency and demand deposit equations of the Board quarterly model. Both equations are estimated from 1961:Q1 - 1986:Q2.
4. Based on the currency, demand deposit and OCD equations of the Board quarterly model. The OCD equation is estimated over 1981:Q3 - 1986:Q3.
5. Based on an aggregate M2 equation estimated over 1968:Q1 - 1986:Q2.
6. Through 1988:Q3.

but jumped to about 7 percentage points in 1988. The currency in circulation equation overpredicted growth in each of the last three years, with annual errors of about 1, 2, and 3 percentage points, respectively.

On balance, the errors in currency in circulation and in the deposit equations result in overall monetary base prediction errors that compared favorably with those of the other aggregates for the simulation period as a whole, with a 1-1/2 percentage point mean absolute error and a bias of one-half percent. However, the surprisingly rapid growth of currency during the first three quarters of 1988 contributed to a nearly 2-1/2 percentage point error in predicted base growth this year. These errors are depicted graphically in Charts 7 and 8.[19]

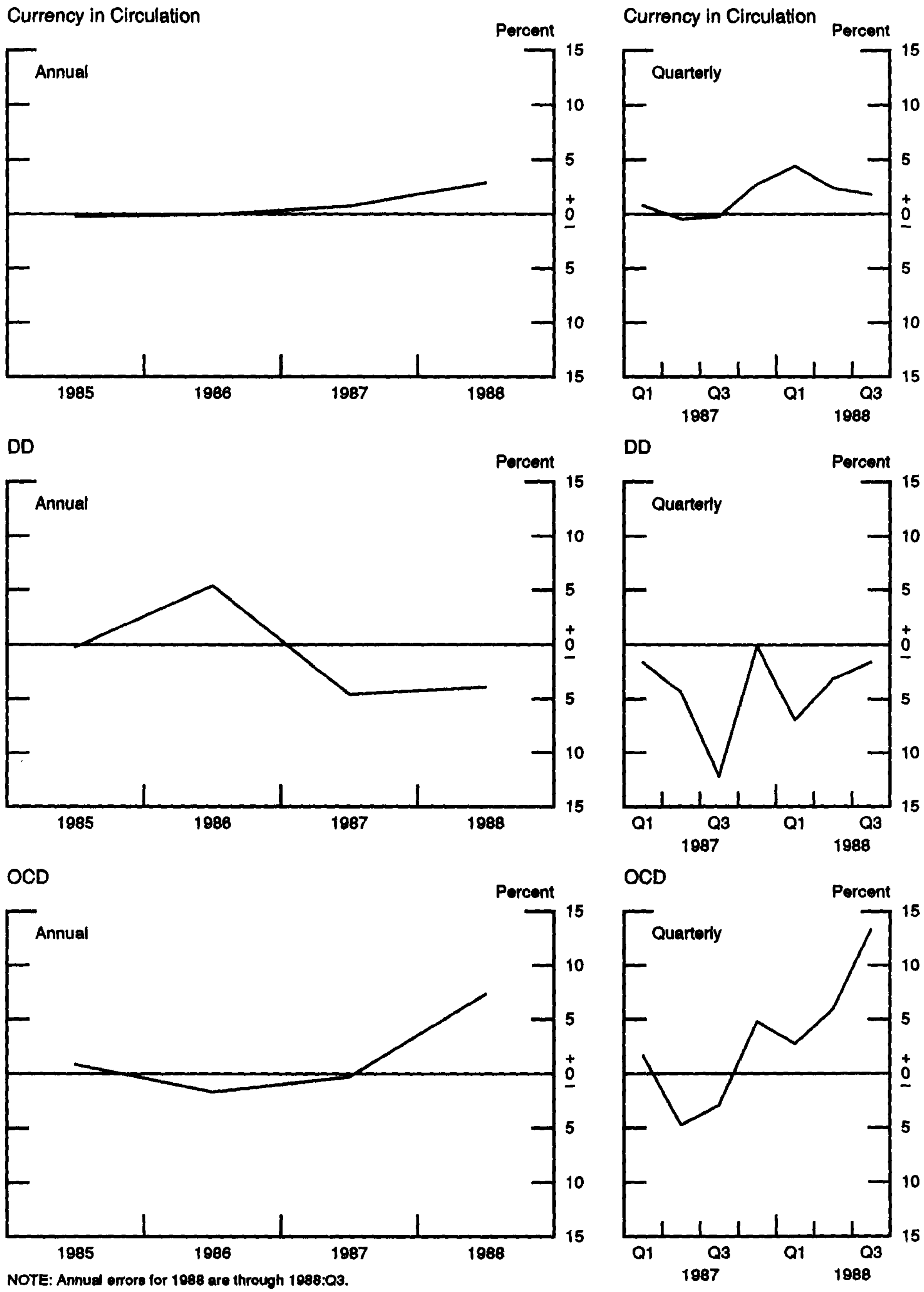
These equations provide information on the sensitivities of demands for the various aggregates to income and interest rates, which may be helpful in assessing their value as targets or indicators for policy. The upper panel of Table 11 shows nominal income elasticities of demands for the various measures. All of the aggregates show some responsiveness to changes in income within one quarter, and all have a nearly complete response within four quarters. (The long-run income

19. A recent study used an alternative specification for demand equations for growth rates of various monetary aggregates, including the monetary base. These equations generally exhibited permanent downward shifts in their constant terms around the beginning of 1981. The study also suggested that, once the change in constant terms is allowed for, the equations have been stable over the entire period since the early 1950s. See Robert H. Rasche, "Demand Functions for U.S. Money and Credit Measures", paper prepared for the Conference on Monetary Aggregates and Financial Sector Behavior in Interdependent Economies, Board of Governors of the Federal Reserve System, Washington, D.C., May 26-27, 1988. As noted above, Board staff deposit demand models include variables related to the introduction of nationwide NOWs, explicitly in the demand deposit equation, and implicitly in the other checkable deposits equation by beginning the estimation in 1981:Q3.

Chart 7

Money Demand Model Growth Rate Errors

Actual minus Predicted

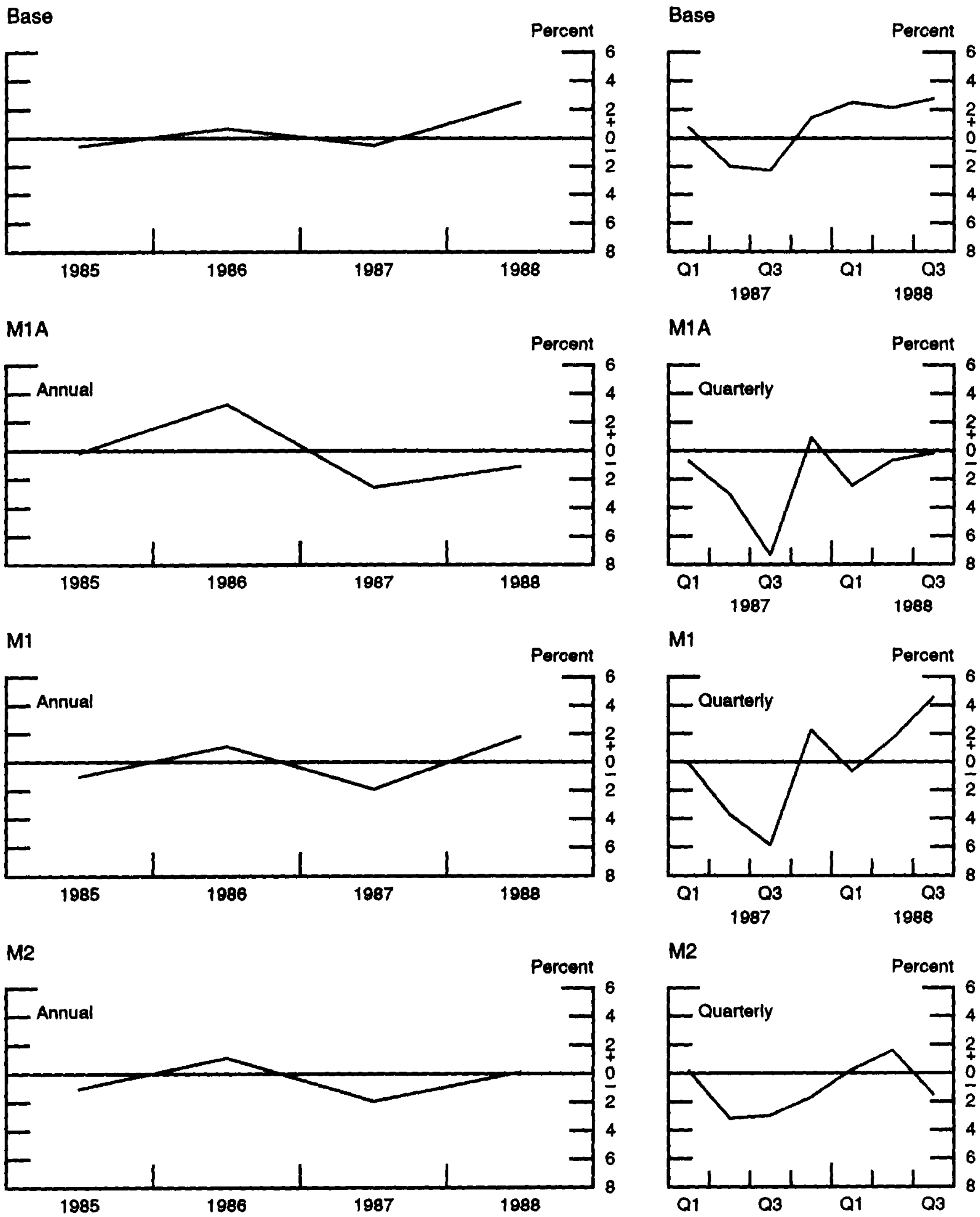


NOTE: Annual errors for 1988 are through 1988:Q3.

Chart 8

Money Demand Model Growth Rate Errors

Actual minus Predicted



NOTE: Annual errors for 1988 are through 1988:Q3.

Table 11

Estimated Properties of the Monetary Aggregates

	NOMINAL INCOME ELASTICITIES			
Time Horizon	Base	M1-A	M1	M2[3]
One quarter	.47	.64	.76	.32
Four quarters	.92	1.02	1.02	.96
Long run[4]	.98	.99	.99	1.00

1. Incorporates estimated response of wealth to changes in income, both of which are used as scale variables in the M2 equation.
2. Long-run income elasticities for all components and aggregates, except those for currency and currency in circulation, are constrained to equal unity in the long-run. The calculated income elasticities assume that one-half of the nominal income shock to the currency equation is real and one half is prices.

	INTEREST ELASTICITIES[2]			
Time Horizon	Base	M1-A	M1	M2
One quarter	-.04	-.03	-.12	-.06
Four quarters	-.08	-.07	-.25	-.13
Long run	-.06	-.09	-.11	-.07

3. For M1-A and M1, based on Board quarterly model; for M2 based on single-equation quarterly aggregate model.
4. With respect to the federal funds rate. Incorporates estimated responses of Treasury bill rates and deposit rates.

elasticities for all of the components and aggregates, except the currency component of the money stock and currency in circulation, are constrained to equal one.) M2 has the smallest estimated short-run income elasticity, while M1 has the highest. The income elasticity of the base is relatively low, reflecting its large currency component, which is estimated to respond fairly slowly to changing income and expenditures.

A relatively high income elasticity--both in the short run and the long run--can be a desirable property for a monetary measure. A high short-run income elasticity implies that movements in income are reflected promptly and relatively completely in money demand, helping monetary policymakers to recognize the shift in income and respond appropriately.

Estimated interest elasticities are presented in the lower panel. Demand for M1 is particularly responsive to movements in interest rates, especially over periods of just a few quarters. The pronounced interest sensitivity of M1 is due importantly to its other checkable deposits component. Because depository institutions adjust interest rates on NOW accounts extremely sluggishly in response to changes in interest rates, such changes lead to large percentage changes in opportunity costs of holding NOW accounts and, hence, large movements in the public's demand for such deposits.

Demand for M1-A is estimated to be less sensitive to interest rates, reflecting the absence of NOW accounts from this measure. However, the pattern of the errors of the demand deposit equation during

1986, 1987, and 1988, noted above, together with movements in interest rates during that period suggest that the estimated interest elasticity of the demand deposit equation may understate the true interest elasticity. Such an underestimate would carry over to the equations for M1-A, M1, and the monetary base. The estimated interest elasticity of demand for the base is low, close to that of M1A, reflecting the small weight of NOW accounts in the base and the relative insensitivity of currency demand to changes in interest rates.

The estimated interest sensitivity of M2 is between that of M1 and M1-A and the base. M2's rate sensitivity is moderated by the pricing of small time deposits, money market mutual funds and, over longer periods, money market deposit accounts (MMDAs). The first two of these accounts are repriced especially promptly in response to changes in market rates, greatly damping movements in opportunity costs.

In the long run, a low interest elasticity is an attractive property for a monetary aggregate. A low interest elasticity means that changes in interest rates will have relatively small effects on money demand, helping to ensure that movements in income and money will be reasonably closely correlated. In the short and intermediate runs, though, a low interest elasticity of a monetary aggregate can cause problems if that aggregate is targeted, because achieving a predetermined path for such an aggregate will require wide swings in interest rates. Such swings may be disruptive to financial markets and destabilizing to the economy, given the possibility of shifts in demand for the targeted aggregate and the delayed response of spending to changing interest rates.

Simulation of a Monetary Base Rule

In order to help determine the monetary targeting implications of the various patterns of interest and income elasticities and degrees of precision of the demand equations for the various aggregates, a simulation experiment was conducted using the Board staff's quarterly econometric model of the U.S. economy (the MPS model). Under these simulations, it was assumed that a given monetary aggregate was controlled tightly along a target path. The target paths for money were established in the following way. The MPS model was first simulated with no shocks, to establish a baseline forecast of relatively stable price and employment behavior. Then, using the demand models for the various monetary aggregates, target paths for the aggregates consistent with that stable behavior were derived, assuming no shocks to the money demand equations. Finally, the full model was simulated repeatedly using historical distributions of shocks to the money demand equations and the other MPS model equations.

The results of these simulations in terms of deviations of ultimate economic variables from baseline paths are reported in Table 12. The table shows estimated standard deviations of nominal GNP, prices, and real GNP from expected paths.

In the monetary base targeting exercise interest rates tended to oscillate explosively. Such oscillations can arise in a monetary

Table 12

ESTIMATED STANDARD DEVIATIONS OF LEVELS OF NOMINAL GNP,
PRICES, AND REAL GNP
USING ALTERNATIVE INTERMEDIATE MONETARY TARGETS[1]

	Base	M1-A	M1	M2
Nominal GNP				
4 quarters	1.8	1.9	1.9	2.0
8	2.1	2.4	2.7	2.9
12	2.7	2.9	3.4	3.6
16	3.5	3.6	4.2	4.7
20	5.0	3.6	4.3	6.1
GNP deflator				
4 quarters	.8	.9	1.0	.9
8	1.7	.9	2.0	2.0
12	2.4	2.8	3.1	3.2
16	2.7	3.3	4.0	4.0
20	3.1	3.5	4.8	4.6
Real GNP				
4 quarters	1.7	1.9	1.8	1.9
8	2.3	2.6	2.4	2.4
12	3.5	3.9	3.4	3.8
16	4.4	4.7	4.5	5.4
20	5.2	4.6	4.8	6.4
Memo: Interest rate variability[2]	3.7	3.3	2.1	n.a.

n.a.--not available.
1. Obtained from stochastic simulations of MPS model. Because of instrument instability, quarter-to-quarter fluctuations in the federal funds rate were constrained to be less than or equal to 500 basis points.
2. Mean absolute quarter-to-quarter changes in the federal funds rate after four quarters.

targeting context when the interest elasticity of money demand is relatively small in the short run, but rises over time, while the elasticity of real spending with respect to interest rates also increases appreciably with time. To deal with this problem, changes in the federal funds rate from quarter to quarter were limited to 5 percentage points in the simulation. This limit was chosen so as to be non-binding for the more interest-elastic aggregates, M1 and M2, but narrow enough to eliminate the interest instability problem of the base.

Over periods of one to two years, which are most relevant for policy targeting, the divergences of ultimate variables from expected paths for the monetary base appear relatively favorable. In general, the standard deviations using the base are of the same order of magnitude as those using the other aggregates, but are generally the smallest. However, it should be emphasized that these simulations required limiting interest rate fluctuations, implying that the apparently attractive performance of the base is due in part to divergences in the base from its simulation target. The simulations suggested that an attempt to target the base more rigidly would lead to large fluctuations in GNP.

Additional information on the issue of interest rate rate variability is presented in the memorandum item on Table 12. It shows mean absolute quarter-to-quarter changes in the funds rate after four quarters. The funds rate variability using M1 is comparatively small, reflecting the comparatively high interest elasticity of demand for those aggregates, but in absolute terms the variability seems rather large at around 2-1/4 percentage points. The estimated rate variability using either M1-A or the base is considerably higher--3-1/4 to 3-3/4 percentage points. This reflects the relatively low interest elasticity of those aggregates and their components. For comparison, the actual mean absolute quarterly change in the federal funds rate between 1983 and 1987 was only about 50 basis points.

Controllability of the Base

Because the monetary base consists of items on the Federal Reserve's balance sheet, it is often claimed that the System can control its growth quite precisely, enhancing its value as an intermediate objective of policy. In fact, this claim is somewhat of an overstatement under long-standing institutional arrangements. For example, the System is unable to control currency growth directly under current policies, as the System supplies currency on demand to depository institutions. Thus, control of the base must take place through its reserves component: fluctuations in currency demand would need to be offset dollar for dollar by total reserves.[20] Moreover, the System is not able to control total reserves precisely. The remaining two-day lag under the current contemporaneous reserve requirement structure means that reserves must be supplied in the last two days of a given maintenance

20. In theory, the System could directly control the quantity of currency in circulation by supplying currency only when it chose. However, this likely would significantly alter the nature of the demand for currency--for example, precautionary demands probably would increase greatly, weakening the link between spending and currency. In addition, the price of currency in terms of reserve balances could fluctuate, in contrast to the par exchange rate that is a result of current System policies.

period either in nonborrowed form or through the discount window to allow the banking system to satisfy its reserve requirements plus excess reserve demands.

Even without the two-day lag, the control mechanism would still be indirect so long as the discount window were open, with use constrained only by administrative pressure, as now. For example, a decline in the nonborrowed base, accomplished through open market operations, could be offset in part by increased borrowing at the discount window. The drop in the nonborrowed base would result in a decline in the total base only to the extent the associated rise in interest rates reduced the quantity of currency and reservable deposits demanded. Ultimately, the nonborrowed base would have to be reduced by a multiple of the desired reduction in the total base. Since these money demand and borrowing relationships are imperfectly predictable, the total base, like the other monetary aggregates, is not susceptible to precise short-run control. Indeed, the nature of the control process for both the base and the other aggregates is qualitatively similar under current institutional arrangements. Thus, a practical operating policy designed to control the monetary base would need to focus on the nonborrowed monetary base in the short run. However, over a longer targeting horizon such as a quarter or more, the total monetary base probably could be controlled closely if the associated interest rate volatility were considered acceptable.

APPENDIX
MODEL DEFINITIONS

Definitions (all variables on a quarterly averge basis)

Base = monetary base

CIC = currency in circulation; seasonally adjusted

CURR = currency + travelers' checks

DD = demand deposits (business and consumer)

EPCE = personal consumption expenditures in 1982 dollars

EPCEN = personal consumption expenditures in current dollars

JNOWT = NOW account availability index (held in constant from 1985 onward)

OCD = other checkable deposits = M1 - currency and travelers' checks - demand deposits

PEPCE = deflator for personal consumption expenditures

ROCDE = own rate on OCDs (effective yield)

(ROCDQ is a weighted average of regular NOW and SuperNOW rates at banks and thrifts through 1986:Q2, with the weights being quantities of deposits lagged one quarter. Survey SuperNOW rates for 1986:Q1 and 1986:Q2 were judgmentally adjusted upward by 22 and 12 basis points, respectively, to reflect blending with regular NOW rates. Starting in 1986:Q3, ROCDQ is a lagged-deposit weighted average of rates of all OCDs at banks and thrifts. ROCDE is simply ROCDQ converted to an effective yield basis.)

RRNPRES = required reserves on nonpersonal reservable deposits

RTBE = rate on 3-month T-bills (effective yield)

RTBOCDE = RTBE - ROCDE (opportunity cost of OCDs)

SHIFT = 0 through 1974:Q2, 1 in 1974:Q3, increments by ones until reaching 10 in 1976:Q4, and remains at ten thereafter (a dummy variable for the "missing money")

TAYLOG1 = log(RTBOCDE) if RTBOCDE ≥ .75
= 1/.75 * RTBOCDE - 1 + log(.75) if RTBOCDE < .75
(becomes the first-order expansion of log for spreads less than .75)

TYME = time variable: 1947:Q1 = 1, increments by 1 each quarter

U = uncorrelated error term (coefficients are autoregressive parameters)

TAYLOG = RM2SP, if RM2SP ≥ SPLICE

$$= \frac{1}{SPLICE} * RM2SP - 1 + \log(SPLICE), \text{ if } RM2SP < SPLICE$$

splice = 0.5

RM2SP = RTBE - RM2E

RTBE = 3 month T-bill rate: effective rate

RM2E = deposit weighted average of deposit own-rates, with weights being stocks lagged one quarter. Deposit own-rates are as defined in quarterly model (ROCDE, RSTDE, RMMDAE, RMMFE, RSAVE) plus rates on overnight Euro and RPs, all on an effective basis

GNP = nominal GNP

DUMMCON = credit control dummy: equals 0 except for 1980:Q2, when it equals 1.

MMDADUM = MMDA dummy: equals 0 during 1982:Q3 and earlier. In 1982:Q4 it equals .1667; in 1983:Q1 and thereafter it equals 1.

WEALTH Excludes land and the stock market.